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Eight-Year Summary of Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units

by
Robert D. Neathammer

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FOREWORD

This research was conducted for the U.S. Army Engineering and Housing Support Center (USAEHSC), under the following Intra Agency Orders (IAOs) from Fort Irwin and Headquarters, U.S. Army Forces Command (FORSCOM): FHAA022-83, dated August 1983; R039-84, dated May 1984; S040-85, dated January 1985; T016-86, dated November 1986; CERL-87, dated December 1987; CERL-88, dated June 1988; CERL-89, dated 2 March 1989; Headquarters, U.S. Army Corps of Engineers (HQUSACE) FAD 90-080031, dated September 1990; (HQUSACE) FAD 91-080025, dated September 1991, and (HQUSACE) FAD 92-080020, dated 10 Aug 92. The USAEHSC technical monitor was Alex Houtzager (CEHSC-HM-O). Other technical advisors from USAEHSC were Robert Lubbert and Joe Hovell. Coordination and advice from FORSCOM were provided by Bill Mann, FCEN-RDM. The Fort Irwin advisors were Tom Cragg and Walt Perry.

The work was performed by the Facility Systems Division (FF), of the Infrastructure Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL). The principal investigator was Robert Neathammer, CECER-FFR. Dr. Janet Spoonamore is Acting Chief, CECER-FF. Dr. Michael J. O'Connor is Chief, CECER-FL. Valuable assistance was provided by Robert F. Doerr, Jr., CECER-FFR.

LTC David J. Rehbein is Commander of USACERL and Dr. L.R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

Congress believes that use of manufactured (factory built) military housing, rather than conventionally built units, will result in lower overall costs and provide durable housing that meets contemporary housing standards. To verify this belief, Congress directed the Department of Defense (DOD) to construct 200 units of manufactured housing at Fort Irwin, CA, and compare them with similarly designed, conventionally built housing.[1] DOD was also directed to perform a study comparing the operation and maintenance (O&M) costs of the two types of construction over a 5-year period. The conditions and parameters for this test were submitted to Congress.

Results of the 5-year study showed no difference in O&M costs between the two types of construction. However, the Assistant Secretary of the Army for Installations, Logistics, and Environment, and managers at the U.S. Army Engineering and Housing Support Center (USAEHSC), and the U.S. Army Construction Engineering Research Laboratories (USACERL) think 5 years is too short a time for valid comparisons of O&M costs. Thus, USACERL was asked to continue collecting and analyzing data and to report results at the end of each year in order to identify broad trends.

The manufactured units met Federal Manufactured Housing Construction and Safety Standards (FMHCSS); however, upgrades in certain criteria were specified to bring the units into conformance with DOD standards. These areas of concern included net usable floor space, energy efficiency, fire and life safety, and durability of certain materials and components. The study compared the impact of the modified FMHCSS versus standard DOD criteria, except for the essential criteria listed in the previous sentence.

The study began when the housing units were first occupied; initial occupancy of some units started in February 1983. The study compares 200 two-bedroom manufactured units to 144 two-bedroom, conventionally built units. The two types of units were similar in floor area, floor plans, and materials used.

The data collected address O&M costs for both types of housing. The study identifies not only the differences, if any, in O&M costs, but also the reasons for the differences and their importance for future construction criteria and construction methods.

Objective

This report summarizes the O&M costs for both conventionally built and manufactured housing from construction through the first 8 years of occupancy.

[1] Report No. 97-44, *Military Construction Authorization Act* (House of Representatives Committee on Armed Services, 1982), pp 8-9.

Approach

The first step was to develop uniform data collection and data analysis procedures. The cost comparisons and analyses for this study were established in USACERL Special Report (SR) P-140.[2] Data were collected throughout the study and summarized/reported yearly. First-year data were reported in USACERL Interim Report (IR) P-85/14;[3] second-year data in USACERL IR P-86/06;[4] third-year data in USACERL IR P-87/10;[5] fourth-year data in USACERL IR P-88/09;[6] 4 1/2-year data in USACERL IP P-89/14;[7] fifth-year data in USACERL TR P-90/11;[8] sixth-year data in USACERL TR P-91/37;[9] and seventh year date in USACERL TR FF-92/08.[10]

Individuals were assigned to quarters with no distinction between the two types of units. The units all have the same floor area and were to be occupied by essentially the same ranks/ages of sponsors; assignment of families was not biased by the type of construction.

Scope

Study costs were limited to the buildings themselves, as the intent of the study was to compare O&M costs of the two types of construction. Thus, sidewalks, driveways, streets, lawns, playgrounds, and utility lines outside the buildings were not included. Also, the replacement costs of refrigerators, kitchen stoves, and utility meters were excluded. (Because of these exclusions, the unit cost data in this report *is not comparable* to standard unit cost data reported for family housing in many Army financial reports, which normally includes costs such as streets and utility lines.)

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[2] M.J. O'Connor, *Fort Irwin Housing Comparison Test*, Special Report (SR) P-140/ADA130349 (USACERL, 1983).

[3] R.D. Neathammer, *Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units*, Interim Report (IR) P-85/14/ADA159740 (USACERL, 1985).

[4] R.D. Neathammer, *Two-Year Summary of Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units*, IR P-86/06/ADA175995 (USACERL, 1986).

[5] R.D. Neathammer, *Three-Year Summary of Fort Irwin, CA, Family Housing Comparison Test; Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units*, IR P-87/10/ ADA180001 (USACERL, 1987).

[6] R.D. Neathammer, *Four-Year Summary of Fort Irwin, CA, Family Housing Comparison Test; Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units*, IR P-88/09/ADA190017 (USACERL, 1988).

[7] R.D. Neathammer, *May 1984 to September 1988 Summary of Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units*, IR P-89/14/ADA209421 (USACERL, 1989).

[8] R.D. Neathammer, *Five-Year Summary of Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units*, TR P-90/11/ADA222176 (USACERL, 1990).

[9] R.D Neathammer, *Six-Year Summary of Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenace Costs of Manufactured vs. Conventionally Built Units*, TR P-91/37/ADA237479 (USACERL, 1991).

[10] R.D. Neathammer, *Seven-Year Summary of Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units*, TR FF-92/08/ADA256255 (USACERL, 1992).

2 REVIEW OF TEST PLAN

USACERL SR P-140 detailed the cost data collection plan and analysis methods. Four basic questions on costs will be answered:

1. Were the average annual O&M costs significantly different?

2. If different, where were they significantly different?

3. Why did the costs differ?

4. What criteria, design features, etc., need to be changed as a result?

Overall maintenance costs and utility costs were compared separately. If significant differences were found, it was important to determine their causes.

In addition to the overall cost comparison, the maintenance costs for major building components were compared. These comparisons provide more detail about where and why cost differences occur.

Occupant satisfaction with the overall apartments and each physical part of the unit was compared for the two types of construction and reported in USACERL P-90/11. When occupant satisfaction differed for a building component, that component was evaluated to determine the reason for the difference.

3 DESCRIPTION OF THE FAMILY HOUSING UNITS

Manufactured Housing Units (MHUs)

These 200 units consist of 50 two-story fourplexes (two units on each of the first and second floors). Net floor area is 950 sq ft/unit.* These were constructed on perimeter footings with wood floors and crawl spaces. Each upper unit has a balcony-porch and each lower unit has a patio with privacy fencing. Figure 1 shows front and rear views of typical buildings. Each unit has a refrigerator, gas range, gas water heater, garbage disposal, dishwasher, central air conditioning, and gas-fired forced-air furnace (all provided by the contractor). Each unit has two bedrooms, a kitchen, living-dining area, one bathroom, a utility room, and a one-car garage. The garage was constructed on site.

A detailed description of the construction process including photographs and floor plans for the units is shown in Appendix A.

The notice to proceed date was 10 January 1983. Initial occupancy was:

61	units	Dec 83
7	units	Jan 84
64	units	Feb 84
57	units	Apr 84
9	units	May 84
2	units	Jun 84

Conventionally Built Units (CBUs)

The 144 units consist of 13 sixplexes, 6 fiveplexes, and 9 fourplexes, all two-story buildings. Net floor area is 950 sq ft/unit. These units were constructed on perimeter footings with building slab. Each unit has two bedrooms, a kitchen, living-dining area, one bathroom, utility room, either a fenced patio or balcony-porch (for upper unit), and a one-car garage. Figure 2 shows front and rear views of typical buildings. The fourplexes have two units on each level. There are two units on the second story in the five- and sixplexes with the additional unit(s) on the first level. The CBUs also have a refrigerator, gas range, gas water heater, garbage disposal, dishwasher, central air conditioning, and gas-fired forced-air furnace.

The notice to proceed date was 3 May 1982. Initial occupancy was:

8	units	Feb 83
28	units	Mar 83
38	units	Apr 83
31	units	May 83
23	units	Jun 83
14	units	Jul 83
2	units	Aug 83

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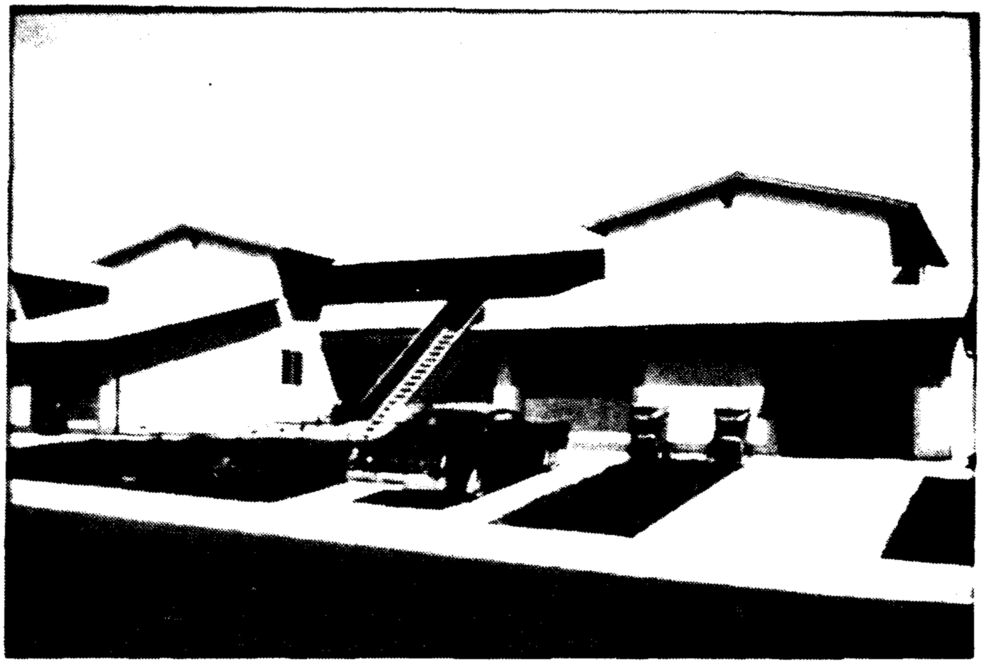
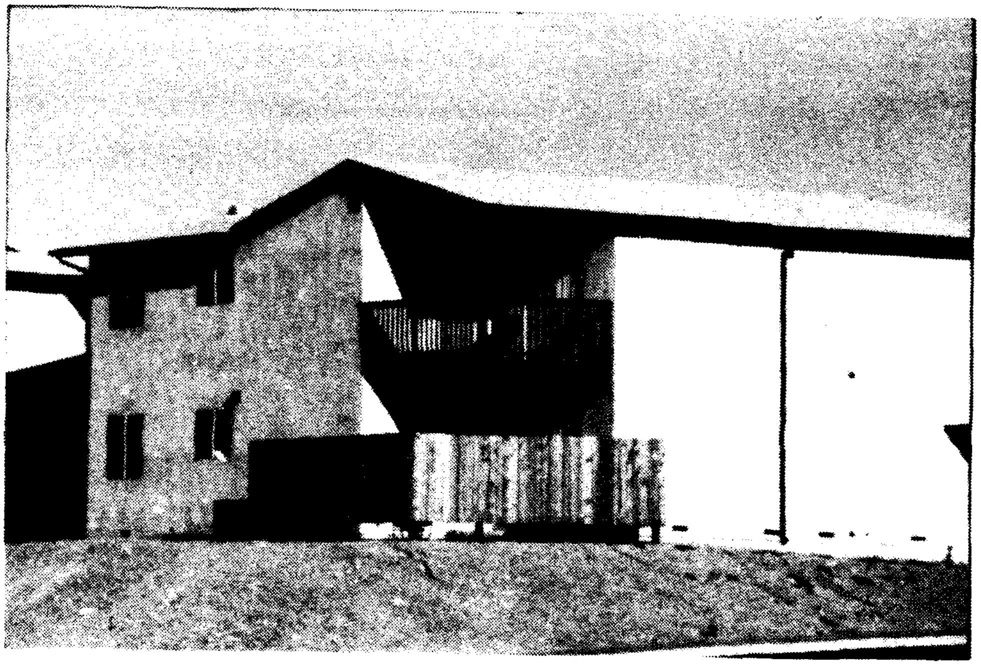
* Metric conversions: 1 cu ft = 0.028 m^3; 1 sq ft = 0.093 m^2; °C = 0.55 x (°F-32).



Front View - MHU



Rear View - MHU

Figure 1. Front and rear views of typical MHUs.

Front View - CBU

Rear View - CBU

Figure 2. Front and rear views of typical CBUs.

A detailed description of all units can be found in the Los Angeles District Office report.[11] The buildings were not specifically adapted to the desert environment but are typical Southern California design.

Costs

A clear-cut initial cost comparison of the two unit types was not possible. The 144 CBUs were part of a project of 254 units. The cost for this project was $51.83/sq ft. The 200 MHUs costs were $51.22/sq ft. However, the supervision and administration costs for the MHUs were based on the same 5 percent rate used for the CBUs. More labor was required since quality assurance inspection was required at the manufacturing plant as well as at the construction site. It was estimated that the additional labor would have raised the cost to $55/sq ft (no records were kept as these are all indirect costs).

General Comparison

Fort Irwin is located in a high desert environment. Annual rainfall averages 4 in. and temperatures often exceed 100 °F. The housing construction was not adapted to this climate but is representative of Southern California design.

The exterior finish of both unit types is stucco with some brick veneer on the garages. Exterior trim is painted wood. Asphalt shingles were used on both types, and gutters and downspouts were installed.

Interior walls are painted gypsum board. Floors on the second level are carpeted and are vinyl tile or vinyl sheet covering on the first floor.

Water piping is copper in the CBUs and polybutylene in the MHUs.

Windows are single pane in the MHUs and thermal pane in the CBUs.

First-story floors in MHUs are wood on crawl spaces and in CBUs are concrete slabs.

Grass was planted in the immediate yard area of the buildings, but not in play yard areas. Each first-floor unit has a concrete patio with a wooden privacy fence; each second-story unit has a wooden balcony-porch.

[11] *Fort Irwin Family Housing Study--A Report on Manufactured/Factory-Built Housing and Site-Built Housing, Fort Irwin, CA* (U.S. Army Corps of Engineers, Los Angeles District, September 1984).

4 DATA COLLECTION PROCEDURES

Data were collected in enough detail that any differences found between the two types of construction could be explained. Appendix B lists the housing units and their identification numbers used in the data collection. Appendix C lists the building components and subcomponents. Each service order was coded to a component so the costs of components could be compared. A discussion of the data collected is included in USACERL SR P-140.

Data Collection

Discussions were held with representatives of the USAEHSC technical monitor; Forces Command Headquarters; Fort Irwin personnel; and the base operations contractor, Boeing Services International (BSI); to establish the best methods of collecting the data.

BSI was contracted to segregate all maintenance service orders for the test units and report the cost data to USACERL through the Fort Irwin Directorate of Engineering and Housing (DEH) monthly. BSI was also contracted to read gas and electric meters at the end of each month and report similarly.

A new contractor, Dynalectron, became the base operations contractor effective 1 October 1986 and has performed the same services.

Data Verification

USACERL verified the reported data several ways. For the first 5 years, each original work order (WO) document was checked against the reported data forwarded by the contractor. Discrepancies were resolved on verification visits to Fort Irwin. Additionally, the contractor set up separate accounting codes for the two groups of units and the total billed was compared to the total obtained from summing all the individual WO data. For years 6 through 8 the reported data was checked for obvious errors, which were resolved with the contractor. No detailed validation of each WO was made as the purpose of the continued study is to search for overall trends.

USACERL developed a computer program to compare gas and electricity meter readings. When apparently erroneous data occurred, the contractor was notified and corrections were made.

Data Analysis

Maintenance Costs

Maintenance costs were compared on a unit-month basis and yearly basis. The data were also summarized by building component to determine if one or more components for one of the types of units had large maintenance costs. If so, the reasons for these costs were determined to help define what criteria or design features should be reviewed/changed.

Cost differences could have been caused by material quality, installation, differences inherent to manufactured or conventional construction, and possible errors in specifications for the two projects.

Warranty work referred to the construction contractor was not included in the cost comparison since no cost data were available or applicable, as it was not a cost to the government. However, the cost of a service call to assess a problem was included.

Energy Consumption

Gas and electricity consumption were compared on a quarterly basis and a yearly basis. Since most of the MHUs were not completed until May 1984, prior energy consumption data for the CBUs was not used in comparisons. (Energy consumption comparisons are valid only for the same time frame because of varying weather conditions.)

5 WHOLE HOUSE ENERGY TESTS

Energy evaluations of sample units of each type of construction were performed immediately after construction was completed on each of the two groups of housing and again after 5 years of occupancy. The objective was to determine if energy characteristics had changed over the 5-year period. Three whole-house energy tests were performed. Appendixes D and E give details of the tests for the CBUs and MHUs, respectively.

House Tightness

The number of air changes per hour were measured with the following results:

	Immediately After Construction			After 5 Years		
Type	No. Units	Average Air Change Per Hour	Standard Deviation (%)	No. Units	Average Air Change Per Hour	Standard Deviation (%)
CBU	15	13.0	1.06	15	12.1	1.70
MHU	12	10.9	2.67	14	9.7	1.60

A statistically significant difference existed between the two types of construction for both the initial and 5-year tests, the MHUs being more airtight on the average. Neither type of unit changed significantly over the 5 years. These results indicate that the MHUs should have had less air infiltration/leakage.

Furnace Efficiency

The furnace efficiency results were as follows:

	Immediately After Construction			After 5 Years		
Type	No. Units	Average Efficiency % Per Hour	Standard Deviation (%)	No. Units	Average Efficiency% Per Hour	Standard Deviation (%)
CBU	13	66.2	6.24	14	64.2	12.2
MHU	16	79.3	3.36	15	77.3	2.84

The furnace efficiencies of the MHUs were significantly higher than those of the CBU for both the initial and 5-year tests. Neither type of unit changed significantly over the 5 years.

Wall Heat Transfer Characteristics

This parameter was not initially measured for the CBUs because of unfavorable weather during the testing period. This parameter was calculated for both types of construction using the designed wall construction.

Type	No. Units	Average Heat Loss (Btu/hr-°F)
CBU	16	1072
MHU	15	1220

Summary

The whole-house energy tests did not conclusively indicate which type of unit would use less energy for heating/cooling. The CBUs are more energy efficient considering only the wall heat loss test, but the MHUs perform better when tested for air tightness and furnace efficiency. Additionally, the CBUs are built on concrete slabs while the MHUs have a crawl space. Houses on concrete slabs use less energy than houses on crawl spaces. This has an impact on the first floor units' energy use.

Therefore, the tests are inconclusive in predicting which type of construction would use more energy for heating/cooling.

6 OPERATION AND MAINTENANCE (O&M) COSTS

O&M costs for ..ch type of unit were compared over the first 8 years of occupancy. The test period for CBUs was 1 August 1983 through 31 July 1991; the test period for MHUs was 1 June 1984 through 31 May 1992.

Overall Costs

The total housing unit-months and maintenance costs for the first 8 years of occupancy are shown in Table 1. (Maintenance includes all types of repairs and "preventive maintenance" performed.)

Discussion

The MHUs cost about $21/month more than the CBUs over the first 8 years of occupancy; the difference in cost per unit per year is $253. There were large increases in M&R costs in years 4, 5, 7, and 8. This is illustrated in Table 2, which shows M&R costs per year of occupancy.

Table 1

Unit/Month Costs in First 8 Years' Occupancy

Type	No. Unit Months	Total Cost ($)	Cost/Unit/ Month ($)	Cost/Unit/ Year ($)
CBU	13,824	552,802	39.99	480
MHU	19,200	1,173,259	61.11	733

Table 2

Yearly M&R Costs by Type of Construction

Year	Total CBU ($)	Cost/Unit ($)	Total MHU ($)	Cost/Unit ($)
1	31,592	219	34,164	171
2	29,107	202	59,076	295
3	44,391	308	63,717	319
4	45,565	316	114,728	574
5	89,186	619	189,122	946
6	96,700	672	175,725	879
7	111,785	776	216,636	1083
8	104,370	725	318,530	1593
8-Year Total	552,802	480	1,173,259	733

Costs per unit have been increasing over time. Figure 3 shows the cumulative costs per unit per month for ages 15 to 96 months, illustrating this trend. The costs for the MHUs increased faster than for the CBUs. This can also be seen in Figure 4, which shows total costs per unit per year.

Increased costs in years 4, 5, and 8 were attributable partly to interior painting done in units vacated for the first time and in those which required painting on change of occupancy. Table 3 shows the painting costs per year of occupancy. Note the large increases for MHUs in year 5 and for CBUs in year 6. Painting costs for the MHUs may have stabilized in years 6 through 8 while costs for CBU's decreased in year 8.

Table 4 lists the yearly costs excluding interior painting. This table shows that the MHUs' costs increased faster than the CBUs' through year 5. Both showed decreases in year 6 and increases in years 7 and 8. Figure 5 displays this data.

Costs Excluding Certain Equipment Costs

Since the purpose of this study was to compare maintenance costs attributable to the method of construction, a comparison was made excluding certain costs. Table 5 gives the costs for the 8 years of occupancy of each type unit, excluding any costs for maintenance of water heaters, garbage disposals, dishwashers, ranges, range hoods, and refrigerators (equipment not part of the construction process).

The difference in cost per unit per year between types of construction is $198/year. Compared to the $253 in Table 1, this is a better estimate of the cost difference attributable to the type of construction.

Costs Excluding Interior Painting and Equipment Costs

In Table 6 equipment costs and painting costs are excluded. The difference for unit cost is $143 per year. Figure 6 graphs the data of Table 6.

Maintenance Per Component

Table 7 lists the frequencies of work orders and costs per building component for the two types of units. However, the costs are not directly comparable across the two types of units since there are 200 MHUs and 144 CBUs. Table 8 shows the cost data adjusted by multiplying the MHU costs by 0.72 (144/200). Also shown in Table 8 are the 8-year costs on a unit basis.

Table 8 shows that the total 8-year cost was less than $1000 for both construction types for 26 of the 78 components. For 41 of the other 52 components, the MHUs had a higher cost.

Most of the costs shown in Tables 7 and 8 were for building components independent of type of construction. For example, about $20K was spent on the ranges (#1003) for each type, $17K for CBUs and $54K for MHUs was spent on dishwashers (#1002), and over $23K was spent on light fixtures (#906) for each type. The most significant costs for components that differ for the types were roofing surface (#101), exterior/storm/screen doors (#209), resilient flooring (#301), interior drywall (#202), garage doors (220), bathroom/kitchen fixtures (#804), lavatories (#805), and water piping (803). Although a large difference existed for painting, this cost depended on rotation of occupants and occupant wear and tear. Complete or extensive quarters painting was done on 336 MHUs and only 193 CBUs.

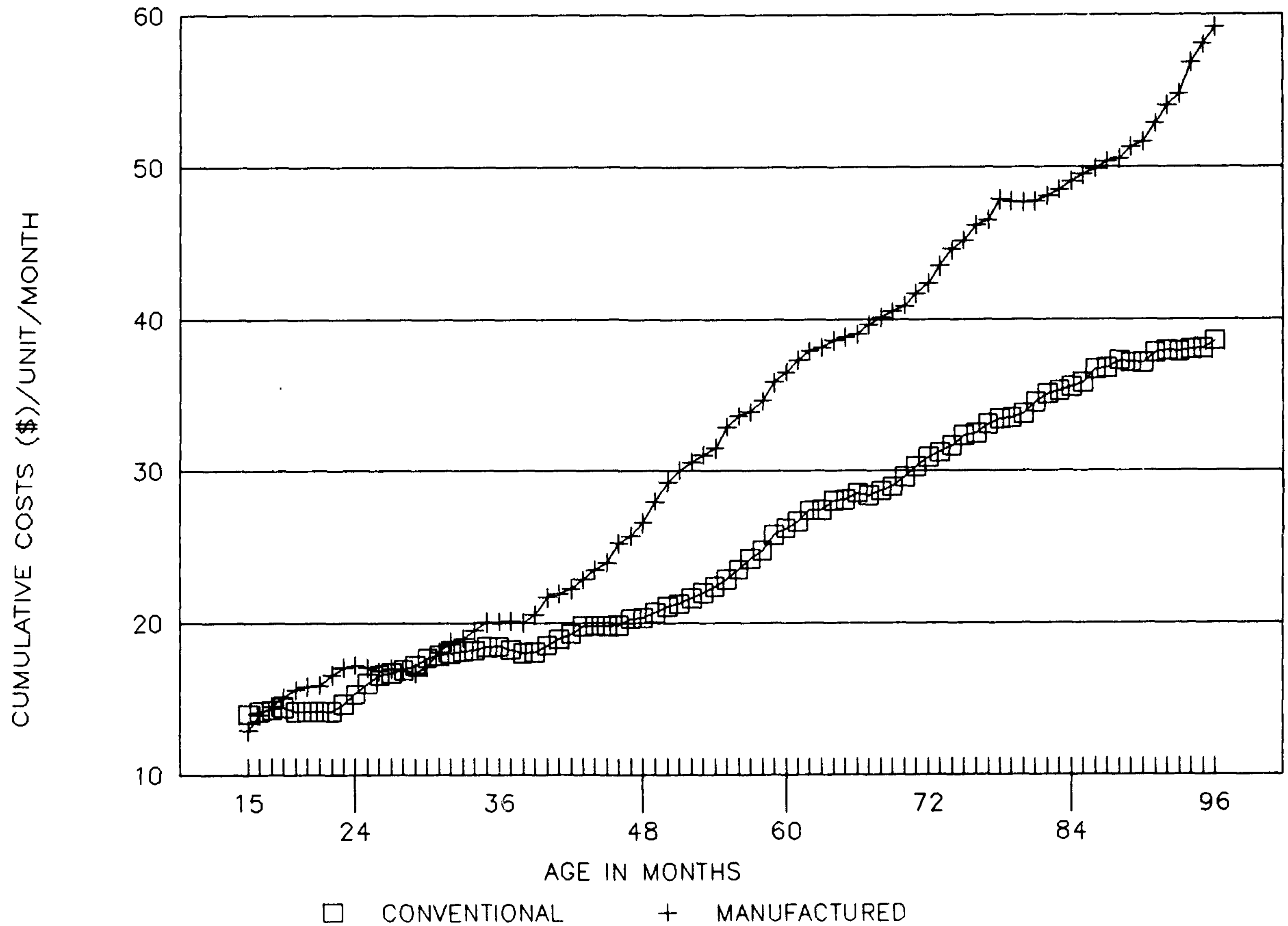


Figure 3. Cumulative cost per unit per month for ages 15 through 96 months.

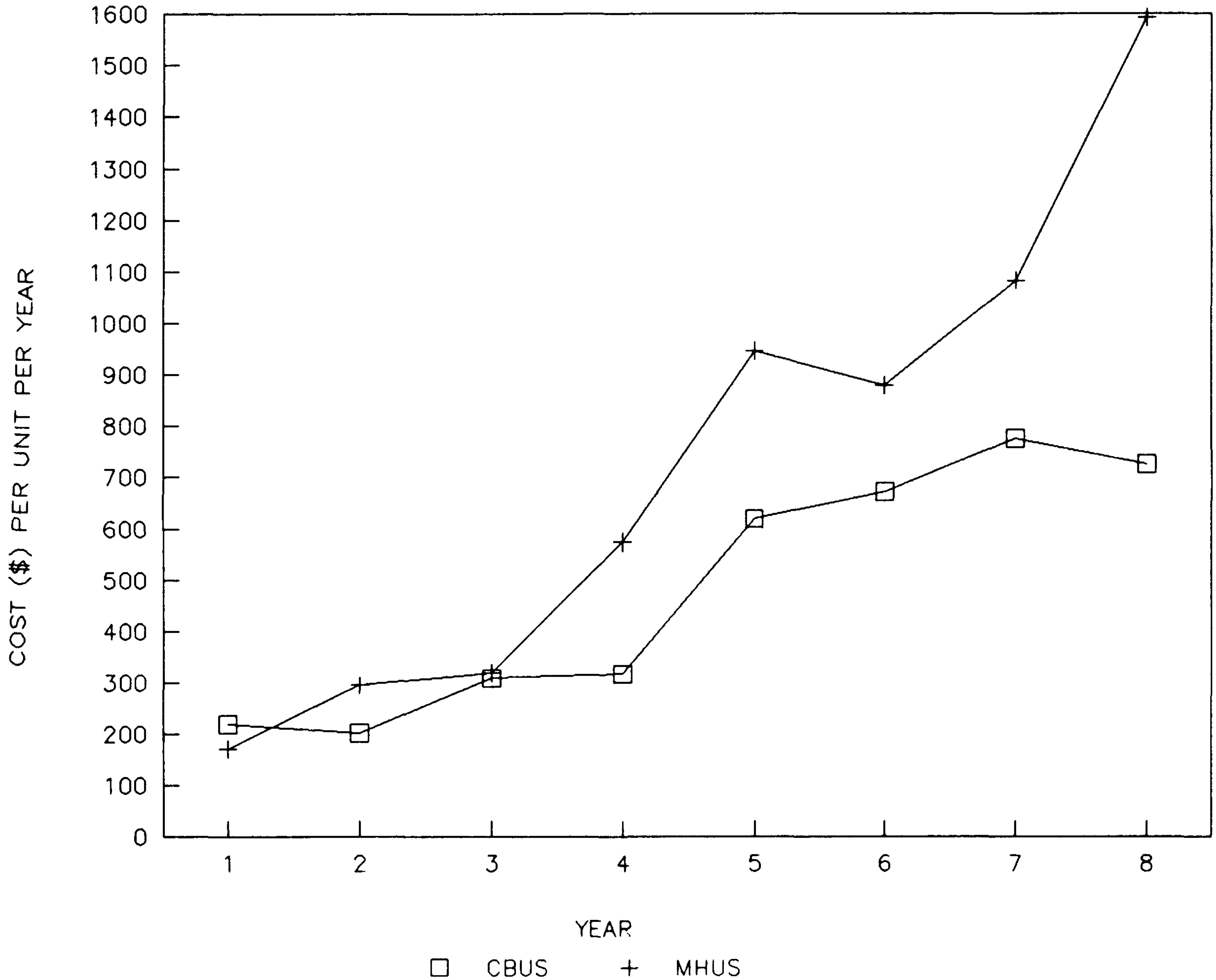


Figure 4. Total costs per unit per year.

Table 3

Interior Painting Costs

Year	Total CBU ($)	Cost/Unit ($)	Total MHU ($)	Cost/Unit ($)
1	603	4	317	2
2	1,288	9	4,684	23
3	7,312	51	13,741	69
4	11,537	80	24,386	122
5	29,779	207	80,499	402
6	49,481	344	74,916	375
7	53,428	371	67,676	338
8	29,642	206	76,050	380
8-Year Total	183,069	159	342,268	214

Table 4

Yearly M&R Costs Excluding Interior Painting Costs

Year	Total CBU ($)	Cost/Unit ($)	Total MHU ($)	Cost/Unit ($)
1	30,989	215	33,905	170
2	27,819	193	54,392	272
3	37,079	257	49,976	250
4	34,028	236	90,342	452
5	59,407	413	108,623	543
6	47,219	328	100,809	504
7	58,357	405	149,677	748
8	74,728	519	242,480	1,212
8-Year Total	369,626	321	830,204	721

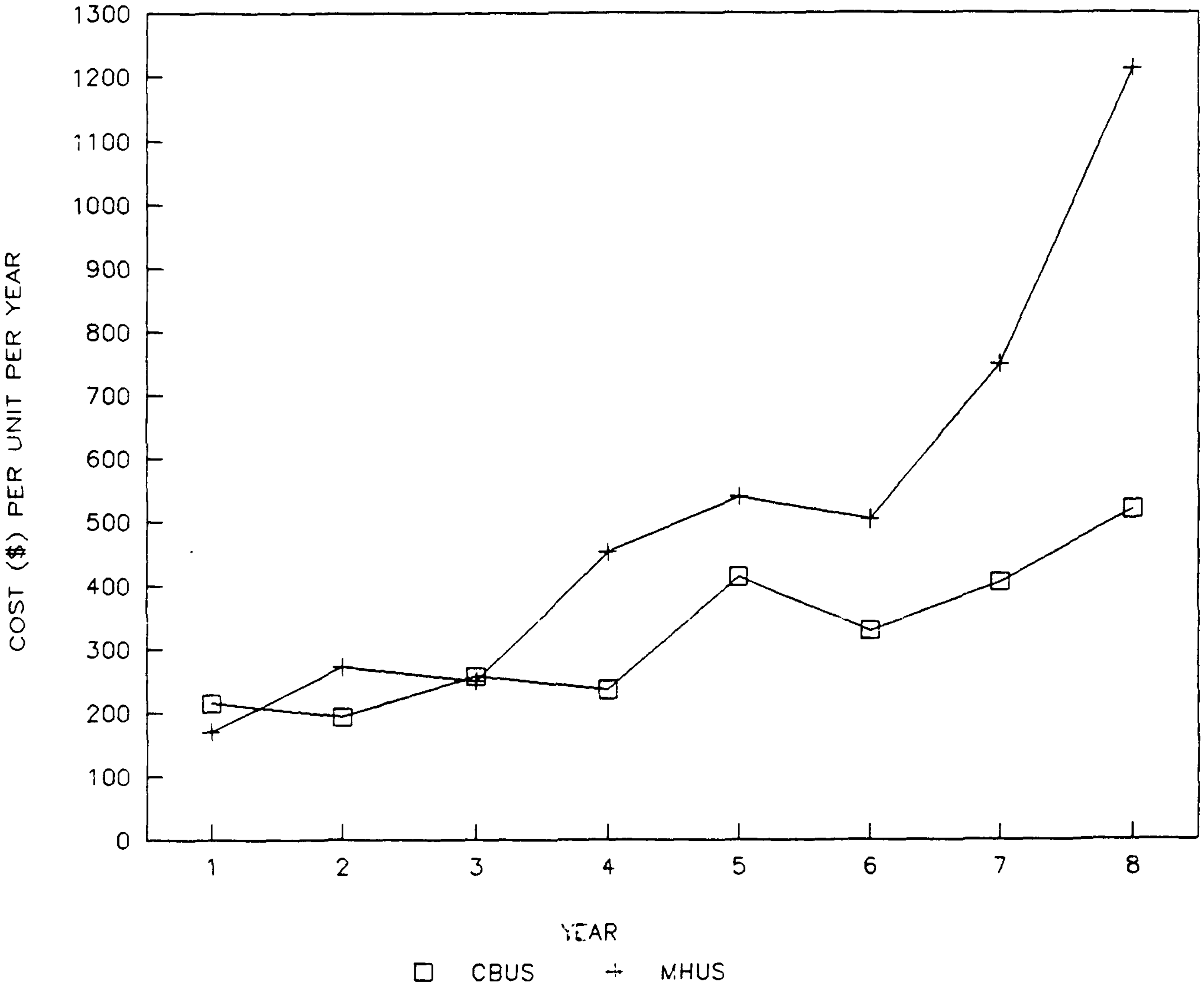


Figure 5. Costs per unit per year excluding interior painting costs.

Table 5

Unit Costs Excluding Certain Equipment Costs

Year	Total CBU ($)	Cost/ Unit ($)	Total MHU ($)	Cost/ Unit ($)
1	25,570	178	26,279	131
2	25,128	174	48,416	242
3	37,275	259	53,789	269
4	40,465	281	96,381	482
5	80,998	562	164,253	821
6	90,662	630	146,019	730
7	102,761	714	196,384	982
8	96,718	672	279,922	1396
8-Year Total	499,559	434	1,011,443	632

Table 6

Unit Costs Excluding Certain Equipment and Painting Costs

	Total Costs ($)		Cost/Unit ($)	
Year	CBU	MHU	CBU	MHU
1	24,967	25,962	173	130
2	23,840	43,732	166	219
3	29,963	40,048	208	200
4	28,928	71,995	201	360
5	51,219	83,754	356	419
6	41,181	71,103	286	356
7	49,227	128,131	342	629
8	67,076	203,872	466	1019
8-Year Total	316,490	669,175	275	418

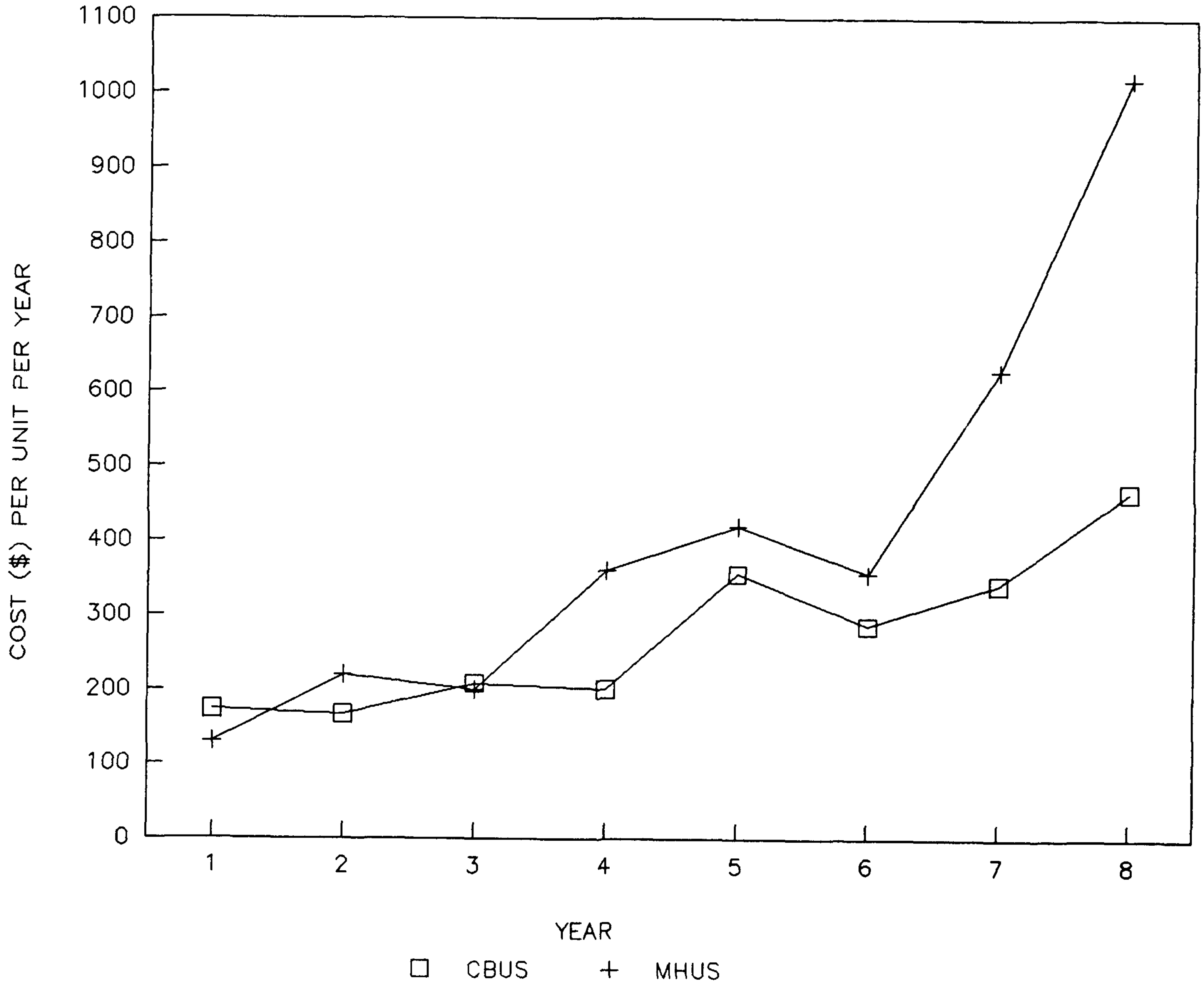


Figure 6. Costs per unit per year excluding certain equipment and painting costs.

Table 7

Maintenance Actions Performed and Costs Per Component

Component		Maintenance/Repair Actions				Cost ($)			
No.	**Description**	**CBU**		**MHU**		**CBU**		**MHU**	
		(N=15,008)*		(N=25,363)		(Total= 552,802)		(Total= 1,173,259	
101	Roofing surface	159	(1%)**	381	(2%)	15349	(2%)	33677	(3%)
103	Flashing, vents	32		15		690		520	
104	Gutters and downspouts	254	(2%)	317	(1%)	3912	(1%)	4797	
105	Other roof repairs	0		2		0		16	
201	Foundation and anchorage	3		2		24		24	
202	Structure	19		66		283		2514	
203	Insulation	3		0		42		0	
204	Masonry	10		11		240		475	
205	Exterior siding	4		2		207		238	
206	Exterior doors and frames	561	(4%)	961	(4%)	12941	(2%)	24646	(2%)
207	Storm and screen doors	708	(5%)	1113	(4%)	21843	(4%)	41581	(4%)
208	Windows and frames	163	(1%)	232	(1%)	3557	(1%)	5872	(1%)
209	Storm windows and screens	364	(2%)	383	(2%)	7867	(1%)	8047	(1%)
210	Exterior trim	0		2		0		26	
211	Porch/deck	5		4		102		142	
212	Interior drywall	245	(2%)	393	(2%)	6261	(1%)	33938	(3%)
213	Wall coverings and paneling	12		0		200		0	
214	Interior doors	1331	(9%)	153	(6%)	24611	(4%)	25142	(2%)
215	Interior casework	47		81		635		1614	
216	Bathroom accessories	201	(1%)	268	(1%)	3732	(1%)	3738	
217	Kitchen accessories, cabinets	360	(2%)	548	(2%)	5497	(1%)	10740	(1%)
218	Drapery hardware	26		100		399		2131	
219	Other exterior/interior	221	(1%)	427	(2%)	7232	(1%)	34302	(3%)
220	Garage doors	638	(4%)	502	(2%)	14533	(3%)	10505	(1%)
301	Resilient flooring	51		322	(1%)	1967		13471	(1%)
302	Carpet and pad	13		64		716		4109	
304	Underlayment/substrate	2		6		13		70	
305	Other flooring	29		178	(1%)	6770		26913	(2%)
401	Paint, walls and ceilings	274	(2%)	417	(2%)	179787	(33%)	332531	(28%)
402	Paint, trim	1		0		20		0	
403	Paint, touchup, interior	97	(1%)	259	(1%)	2412		8772	(1%)
404	Bathtub, shower caulking	240	(2%)	429	(2%)	2964	(1%)	6707	(1%)
405	Other interior painting	35		22		851		964	
501	Paint, exterior walls	3		3		92		45	
502	Paint, exterior doors, frames	5		4		138		79	
503	Paint, exterior trim	0		13		0		17767	(2%)
504	Exterior caulking	0		1		0		20	
506	Other exterior painting	2		3		44		75	

*N = Number of maintenance actions

**Percents are given for number maintenance actions and costs when the value is 1% or more of the total.

Table 7 (Cont'd)

Component		Maintenance/Repair Actions				Cost ($)			
No.	Description	CBU		MHU		CBU		MHU	
		(N=15,008)*		(N=25,363)		(Total= 552,802)		(Total= 1,173,259	
601	Heating plant, valve	102	(1%)	55		3617	(1%)	2855	
602	Motors, blowers, pumps	60		83		4277	(1%)	5529	
603	Ducts	1		34		15		2200	
604	Piping	7		3		190		124	
605	Diffusers, grills	13		65		202		920	
606	Insulation	0		2		0		61	
607	Heating controls	142	(1%)	101		6112	(1%)	4447	
608	Other heating	499	(3%)	803	(3%)	7921	(1%)	16597	(1%)
701	Cooling coils, compressor	46		44		8835	(2%)	2386	
702	A/C motors, blowers, pumps	98	(1%)	117		7314	(1%)	5928	(1%)
703	A/C piping, ducting	7		40		180		1194	
704	A/C refrigerant	393	(3%)	205	(1%)	13809	(3%)	7004	(1%)
705	A/C insulation	1		0		7		0	
706	A/C controls	100	(1%)	84		4336	(1%)	3314	
707	Other cooling	721	(5%)	1067	(4%)	19997	(4%)	28310	(2%)
801	Water heater	284	(2%)	556	(2%)	6304	(1%)	19983	(1%)
803	Piping, supply	144	(1%)	955	(4%)	4882	(1%)	59309	(5%)
804	Faucets and shower heads	662	(4%)	1640	(6%)	16707	(3%)	42320	(4%)
805	Lavatories	390	(3%)	1033	(4%)	6530	(1%)	29704	(3%)
806	Water closets	740	(5%)	1208	(5%)	14161	(3%)	25275	(2%)
807	Bathtub/shower unit	123	(1%)	455	(2%)	2024		11304	(1%)
809	Other plumbing	206	(1%)	530	(2%)	4436	(1%)	16238	(1%)
901	Service entrance	2		2		65		188	
902	Panel box/circuit breakers	69		172	(1%)	2264		7528	(1%)
903	Branch circuits	19		21		532		1358	
904	Wall receptacles	312	(2%)	554	(2%)	5418	(1%)	11562	(1%)
905	Doorbells and chimes	1		1		15		4	
906	Light fixtures	1350	(9%)	1461	(6%)	23841	(4%)	33552	(3%)
907	Vents, fans	43		56		872		1310	
908	Other electrical	42		49		1121		3876	
1001	Garbage disposal	372	(2%)	781	(3%)	7225	(1%)	18965	(2%)
1002	Dishwasher	328	(2%)	1015	(4%)	17568	(3%)	75285	(6%)
1003	Range	809	(5%)	1285	(5%)	17951	(3%)	27186	(2%)
1004	Range hood	74		111		1190		1980	
1005	Refrigerator	152	(1%)	559	(2%)	3004		18415	(2%)
1006	Other equipment	150	(1%)	235	(1%)	1511		2954	
1201	Water supply	81	(1%)	159	(1%)	2023		5501	
1202	Gas supply	83	(1%)	126		2386		3467	
1203	Electrical service	57		82		5063	(1%)	7341	(1%)
1204	Sanitary/sewer lines	5		4		657		191	
1205	Other utility service	0		1		0		8	
1300	Miscellaneous	202	(1%)	346	(1%)	2286		11047	(1%)

Table 8

Maintenance Costs Per Component, Adjusted by Number of Units

Component		Costs ($)				
No.	Description	CBU	MHU	MHU Adjusted*	CBU/144**	MHU/200**
101	Roofing surface	15349	33677	24247	106.59	168.39
103	Flashing, vents	690	520	374	4.79	2.60
104	Gutters and downspouts	3912	4797	3454	27.17	23.99
105	Other roof repairs	0	16	12	0.00	0.08
201	Foundations and anchorage	24	24	17	0.17	0.12
202	Structure	283	2514	1810	1.97	12.57
203	Insulation	42	0	0	0.29	0.00
204	Masonry	240	475	342	1.67	2.38
205	Exterior siding	207	238	171	1.44	1.19
206	Exterior doors and frames	12941	24646	17745	89.87	123.23
207	Storm and screen doors	21843	41581	29938	151.69	207.91
208	Windows and frames	3557	5872	4228	24.70	29.36
209	Storm windows and screens	7867	8047	5794	54.63	40.24
210	Exterior trim	0	26	19	0.00	0.13
211	Porch/deck	102	142	102	0.71	0.71
212	Interior drywall	6261	33938	24435	43.48	169.69
213	Wall coverings and paneling	200	0	0	1.39	0.00
214	Interior doors	24611	25142	18102	170.91	125.71
215	Interior casework	635	1614	1162	4.41	8.07
216	Bathroom accessories	3732	3738	2691	25.92	18.69
217	Kitchen accessories, cabinets	5497	10740	7733	38.17	53.70
218	Drapery hardware	399	2131	1534	2.77	10.66
219	Other exterior/interior	7232	34302	24697	50.22	171.51
220	Garage doors	14533	10505	7564	100.92	52.53
301	Resilient flooring	1967	13471	9699	13.66	67.36
302	Carpet and pad	716	4109	2958	4.97	20.55
304	Underlayment/substrate	13	70	50	0.09	0.35
305	Other flooring	6770	26913	19377	47.01	134.57
401	Paint, walls and ceilings	179787	332531	239422	1248.52	1662.66
402	Paint, trim	20	0	0	0.14	0.00
403	Paint, touchup, interior	2412	8772	6316	16.75	43.86
404	Bathtub, shower caulking	2964	6707	4829	20.58	33.54
405	Other interior painting	851	964	694	5.91	4.82
501	Paint, exterior walls	92	45	32	0.64	0.23
502	Paint, exterior doors, frames	138	79	57	0.96	0.40
503	Paint, exterior trim	0	17767	12791	0.00	88.84
504	Exterior caulking	0	20	14	0.00	0.10
506	Other exterior painting	44	75	54	0.31	0.38
601	Heating plant, valve	3617	2855	2056	25.12	14.28

*The MHU column adjusted by multiplying by 0.72.

**These are costs per unit for the 8 years.

Table 8 (Cont'd)

Component		Costs ($)				
No.	Description	CBU	MHU	MHU Adjusted*	CBU/144**	MHU/200**
602	Motors, blowers, pumps	4277	5529	3981	29.70	27.65
603	Ducts	15	2200	1584	0.10	11.00
604	Piping	190	124	89	1.32	0.62
605	Diffusers, grills	202	920	662	1.40	4.60
606	Insulation	0	61	44	0	0.31
607	Heating controls	6112	4447	3202	42.44	22.24
608	Other heating	7921	16597	11950	55.01	82.99
701	Cooling coils, compressor	8835	2386	1718	61.35	11.93
702	A/C motors, blowers, pumps	7314	5928	4268	50.79	29.64
703	A/C piping, ducts	180	1194	860	1.25	5.97
704	A/C refrigerant	13809	7004	5043	95.90	35.02
705	A/C insulation	7	0	0	0.05	0.00
706	A/C controls	4336	3314	2386	30.11	16.57
707	Other cooling	19997	28310	20383	138.87	141.55
801	Water heater	6304	19983	14388	43.78	99.92
803	Piping, supply	4882	59309	42702	33.90	296.55
804	Faucets and shower heads	16707	42320	30470	116.02	211.60
805	Lavatories	6530	29704	21387	45.35	148.52
806	Water closets	14161	25275	18198	98.34	126.38
807	Bathtub/shower unit	2024	11304	8139	14.06	56.52
809	Other plumbing	4436	16238	11691	30.81	81.19
901	Service entrance	65	188	135	0.45	0.94
902	Panel box/circuit breakers	2264	7528	5420	15.72	37.64
903	Branch circuits	532	1358	978	3.69	6.79
904	Wall receptacles	5418	11562	8325	37.63	57.81
905	Doorbells and chimes	15	4	3	0.10	0.02
906	Light fixtures	23841	33552	24157	165.56	167.76
907	Vents, fans	872	1310	943	6.06	6.55
908	Other electrical	1121	3876	2791	7.78	19.38
1001	Garbage disposal	7225	18968	13657	50.17	94.84
1002	Dishwasher	17568	75285	54205	122.00	376.43
1003	Range	17951	27186	19574	124.66	135 .93
1004	Range hood	1190	1980	1426	8.26	9.90
1005	Refrigerator	3004	18415	13259	20.86	92.08
1006	Other equipment	1511	2954	2127	10.49	14.77
1201	Water supply	2023	5501	3961	14.05	27.51
1202	Gas supply	2386	3467	2496	16.57	17.34
1203	Electrical service	5063	7341	5286	35.16	36.71
1204	Sanitary/sewer lines	657	191	138	4.56	0.96
1205	Other utility service	0	8	6	0.00	0.04
1300	Miscellaneous	2286	11047	7954	15.88	55.24
	Totals	552,802	1,173,259	844,746		

Note the $17,767 cost for exterior-trim painting of MHUs and $0 for CBUs (component no. 503). The exterior trim was to be painted on a cyclic basis. The CBU cycle in 1988 was deferred. Both CBU and MHU exterior-trim painting for 1989-92 was deferred.

Table 9 groups the Table 10 data into the 12 major building component codes (Appendix C). Although the 0201-0220 structure is a high cost item, Table 8 shows most of these costs are related to doors and windows, and some of the damage to these items was caused by the occupant. Note the plumbing costs for the MHUs is 2.7 times that for the CBUs.

Water Piping Problems

The manufacturer used polybutylene piping in the CBU units. The piping was installed in the building modules at the plant in Southern California and many connections made after the modules were assembled at Fort Irwin (after 200 miles of transportation).

These manufactured apartments are two-story fourplexes; two units above two units. Piping runs through walls, the ceiling of the first floor units (i.e., the floor of the upper units) and under the first floor units in the crawl space.

There have been many leaks in the piping with several major breaks in a "tee" joint in the ceiling of the first floor units of the MHUs. A detailed analysis of plumbing service orders shows a higher cost for MHUs for the category leaking or broken piping. Costs for each of the 8 years are shown in Table 10.

Most leaks are breaks of the hard plastic tees and valves, usually under the crimped metal band. The problem is so bad that all piping is to be replaced. A contract was executed for replacement in one building to develop the methods and to get a better idea of the cost.

This is not a new problem in the plastic pipe industry. A "60 Minutes" television program shown in December 1990, described many problems in the Southwest with such materials. The companies paid required repairs because the plastic material itself was defective.

Appendix F is a copy of a report on the USACERL investigation into the piping problem. Conclusions on page 92 include: "Because of the choice of materials by the contractors who built and erected the housing units and the workmanship allowing the pipes to be crushed or flattened and nails to be driven into them, the plumbing system in the pre-manufactured housing area is failing and will continue to fail...the entire piping system should be abandoned in-place and replaced with a new system." The current estimate to replace piping in all 200 units (50 buildings) is $1.23 million or about $6,125/Unit.

Summary of M&R Costs

In year 8, the MHUs cost $1593 - $725 = $868/unit more (statistically significant) than the CBUs overall and $1019 - $466 = $555 more excluding certain equipment and painting costs. About $158 of these differences was due to water piping alone. The $555 - $158 = $397 difference for overall M&R costs in year 8 is significant.

Figure 7 shows the number of units incurring costs in various ranges. Note that MHUs dominate the higher costs ranges (above $500) i.e., in year 8, many more MHUs had M&R costs above $500 than did CBUs.

Table 9

Maintenance Actions Performed and Costs for Component Group, 8-Year Summary

Component Group	Description	Maintenance/Repair Actions CBU (N=15,008)		Maintenance/Repair Actions MHU (N=25,363)		Cost ($) CBU (Total = 552,802)		Cost ($) MHU (Total = 1,173,259		MHU Adjusted (Total = 844,746)
0101-0105	Roofing	445	(3%)	715	(3%)	19,951	(4%)	39,009	(3%)	28,086
0201-0220	Structure	4,921	(33%)	6,821	(27%)	110,226	(20%)	205,675	(8%)	148,086
0301-0305	Floor coverings	95	(1%)	570	(2%)	9,466	(2%)	44,562	(4%)	32,085
0401-0405	Interior painting	647	(4%)	1127	(4%)	186,034	(34%)	348,975	(30%)	251,262
0501-0506	Exterior painting	10	(0%)	24	(0%)	274	(0%)	17,985	(2%)	12,949
0601-0608	Heating	824	(5%)	1146	(5%)	22,335	(4%)	32,754	(3%)	23,568
0701-0707	Air conditioning	1,366	(9%)	1,557	(6%)	54,473	(10%)	48,136	(4%)	34,658
0801-0809	Plumbing	2,549	(17%)	6,377	(25%)	55,043	(10%)	204,131	(17%)	146,974
0901-0908	Electrical	1,838	(12%)	2,316	(9%)	34,129	(6%)	59,378	(5%)	42,752
1001-1006	Equipment	1,885	(13%)	3,986	(16%)	48,450	(9%)	144,733	(12%)	104,247
1201-1205	Utility service	226	(2%)	372	(1%)	10,130	(2%)	16,507	(1%)	11,885
1300	Miscellaneous	202	(1%)	346	(1%)	2286	(0%)	11,047	(19%)	7,954

Table 10

Water Piping Costs

Year	CBUs ($)	MHUs ($)
1	776	1,134
2	473	2,524
3	408	758
4	408	1,769
5	108	2,462
6	487	4,870
7	557	12,458
8	1,665	33,332
Total	4,882	59,309

The two major deficiencies found in the MHUs to date were the improperly installed hingeable eaves and the water piping. Both of these were caused by improper design (eaves), improper material specification, and poor quality workmanship (water piping). Neither of these problems is considered a defect due to the type of construction—manufactured. Although they are not due to type of construction, in this instance at Fort Irwin, the project will cost the Army an additional $334,600 (eaves repair) + $1,225,000 (piping replacement) = $1,559,600 ($7800 per unit), which would not have occurred if the same conventional construction had been used as in the 144 units.

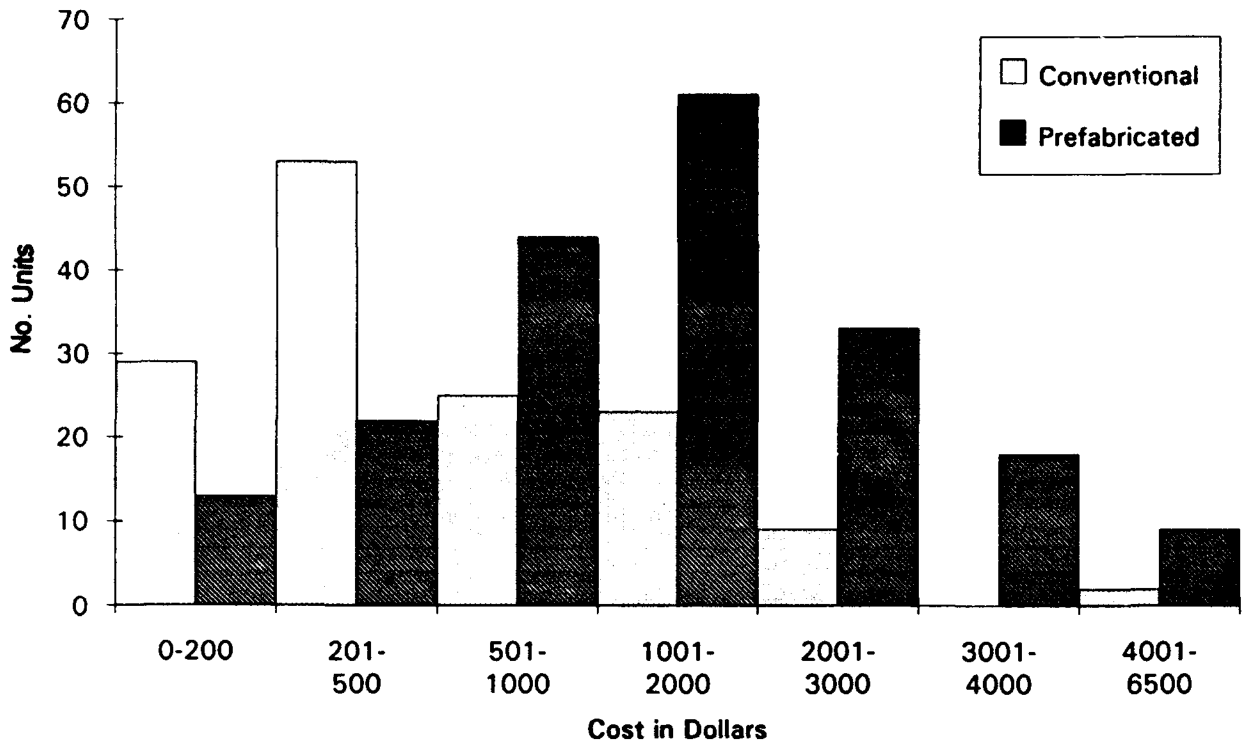


Figure 7. Histogram of year 8 M&R costs.

7 ENERGY COSTS

Comparisons of gas and electricity consumption began in May 1984, since most MHUs were not occupied before then.

Electricity Consumption

The average quarterly electric usage (in kWh) per housing unit is shown in Table 11 and Figure 8. The MHUs had higher average consumptions than the CBUs in 16 of the 28 quarters and always higher in the summer quarter, Jun-Aug. For the entire 96-month data collection period, an MHU used an average total of 74,233 kWh, while a CBU used an average total of 73,271 kWh. This was a difference of 962 kWh ÷ 96 months = 10.02 kWh/month. At the August 1992 rate of $0.0666/kWh, an MHU cost $0.67 more than a CBU for electricity per month. Average yearly electricity usage is shown in Figure 9.

Gas Consumption

The type of fuel used was liquid propane (LP). LP is delivered to a central facility on post and is converted to gas and distributed to housing units through underground pipes. The average quarterly usage (cu ft) per housing unit is shown in Table 12 and Figure 10.

For the 96-month period, an MHU used an average total of 151,965 cu ft while a CBU used an average total of 141,351 cu ft. The MHUs had higher average consumptions in 26 of the quarters, always higher in the winter, Dec-Feb, and in seven of the eight spring quarters, Mar-May. This is a difference of 10,614 cu ft ÷ 96 months = 126 cu ft/month. At the August 1992 cost of $0.01530/cu ft, an MHU cost $1.93 more than a CBU for gas per month. Average yearly gas usage is shown in Figure 11.

Statistical Analysis of Consumption

One-way analysis of variance tests showed significant differences among the 8 years of data for gas and electricity consumption for each of the types of construction.

T-tests were performed comparing the construction types for each year for both gas and electricity consumption. Results are shown below:

Average Consumptions for Each Year

		1	2	3	4	5	6	7	8
Electricity	MHUS	8613	9027	8895	8959	9658	9223	9255	9956
(kWh)	CBUS	8195	8757	9093	9255	9654	9358	9054	10251
Gas	MHUS	21340*	18020*	19320	19360	19060	16650*	20140*	16050
(Cu Ft)	CBUS	19200	16810	19010	19880	18170	18320	17480	17780

An asterisk (*) means there is a statistically significant difference between the types of construction for average unit consumption for a year. (Tests were at the 99% confidence level.) Note there were no significant differences for electricity consumption.

Total Energy Consumption

The total energy consumption for the housing units is shown in Table 13. It was calculated by converting the gas and electricity consumption data to MBTU/KSF. (One cubic foot of propane gas = 2618.5 BTU and one kWh of electricity = 3413 BTU.) The area of the housing units is approximately 950 sq ft, so a multiplier of 1000/950 = 1.053 was used to convert usage to kilowatts per square foot.

Cost Comparison Summary

The averages for dwelling unit energy consumption and cost for the 8-year period (May 1984 to April 1992) are given in Table 14. The MHUs on the average have cost $28 more (3%) per year for gas and electricity than the CBUs.

Meter Problems

Many meters have become defective over the past 8 years. For the CBUs, 46 electric and 9 gas meters have failed while for the MHUs 20 electric and 4 gas have failed.

Comments

The data in Chapter 5 (better air tightness and higher furnace efficiencies for the MHUs) would indicate the MHUs should use less energy than the CBUs. However, this is offset by the higher overall heat loss of the MHUs. Detailed energy simulations (performed using the Building Loads Analysis and System Thermodynamics* program) indicate two design/construction features that cause the higher wall-heat loss: the MHUs have more window/door glass area; and the MHUs have single-pane glass while the CBUs have thermal-pane. Additionally, the CBUs were built on concrete slabs while the MHUs have crawl spaces, which are less energy efficient.

*The Building Loads Analysis and System Thermodynamics (BLAST) program was developed by USACERL and is used throughout the Department of Defense for military construction projects.

Table 11

Average Quarterly Electricity Consumption (kWh) Per Housing Unit

	1984 Jun-Aug	Sep-Nov	1984-5 Dec-Feb	1985 Mar-May	Jun-Aug	Sep-Nov	1985-6 Dec-Feb	1986 Mar-May
MHU	3492	2005	1399	1737	4053	1743	1470	1763
CBU	3263	1925	1353	1655	3752	1857	1410	1738

	1986 Jun-Aug	Sep-Nov	1986-7 Dec-Feb	1987 Mar-May	Jun-Aug	Sep-Nov	1987-8 Dec-Feb	1988 Mar-May
MHU	3951	1778	1500	1725	3644	2191	1483	1702
CBU	3683	1934	1630	1813	3550	2411	1494	1768

	1988 Jun-Aug	Sep-Nov	1988-9 Dec-Feb	1989 Mar-May	Jun-Aug	Sep-Nov	1989-90 Dec-Feb	1990 Mar-May
MHU	3738	2366	1550	1996	3892	2192	1523	1750
CBU	3513	2445	1610	2024	3634	2180	1478	1823

	1990 Jun-Aug	Sep-Nov	1990-1 Dec-Feb	1991 Mar-May	Jun-Aug	Sep-Nov	1991-92 Dec-Feb	1992 Mar-May
MHU	3796	2349	1467	1624	3670	2641	1615	2037
CBU	3406	2252	1600	1730	3616	2650	1680	2237

Table 12

Average Quarterly Gas Consumption (cu ft) Per Housing Unit

	1984 Jun-Aug	Sep-Nov	1984-5 Dec-Feb	1985 Mar-May	Jun-Aug	Sep-Nov	1985-6 Dec-Feb	1986 Mar-May
MHU	1890	4400	10050	5130	1890	4440	7670	4020
CBU	1780	3730	9200	4500	1840	3970	7080	3950
	1986 Jun-Aug	Sep-Nov	1986-7 Dec-Feb	1987 Mar-May	Jun-Aug	Sep-Nov	1987-8 Dec-Feb	1988 Mar-May
MHU	1800	3810	9340	4390	1910	3300	9930	4740
CBU	2130	3520	9070	4500	2160	3430	9500	4460
	1988 Jun-Aug	Sep-Nov	1988-9 Dec-Feb	1989 Mar-May	Jun-Aug	Sep-Nov	1989-90 Dec-Feb	1990 Mar-May
MHU	1880	3490	10000	3700	1940	3370	9150	4010
CBU	1960	3250	9400	3550	1960	3140	8160	3390
	1990 Jun-Aug	Sep-Nov	1990-1 Dec-Feb	1991 Mar-May	Jun-Aug	Sep-Nov	1991-92 Dec-Feb	1992 Mar-May
MHU	1850	3350	9210	6070	1810	3190	8690	4080
CBU	1790	2920	7810	4950	1730	2780	7590	3950

Table 13

Total Energy Consumption

	MHU		CBU	
	Gas (cu ft)	**Electricity (kWh)**	**Gas (cu ft)**	**Electricity (kWh)**
8 year total	151,965	74,233	141,351	73,271
Yearly average	18,996	9,279	117,669	9,159
MBTU/year	49.65	31.67	46.26	31.26
Total energy per year	81.32 MBTU		77.52 MBTU	
Conversion to MBTU/ksq ft	85.60 MBTU/yr		81.60 MBTU/yr	

(MBTU = million British thermal units, CF = cubic feet)

Table 14

Eight-Year Summary of Energy Consumption

	MHU		CBU	
	Gas (cu ft)	**Electricity (kWh)**	**Gas (cu ft)**	**Electricity (kWh)**
Average Consumption/Year Per Housing Unit	18,996	9,279	78,669	9,158
Average Cost/Year Per Housing Unit	$290	$618	$270	$610
Total Cost/Year	$908		$880	

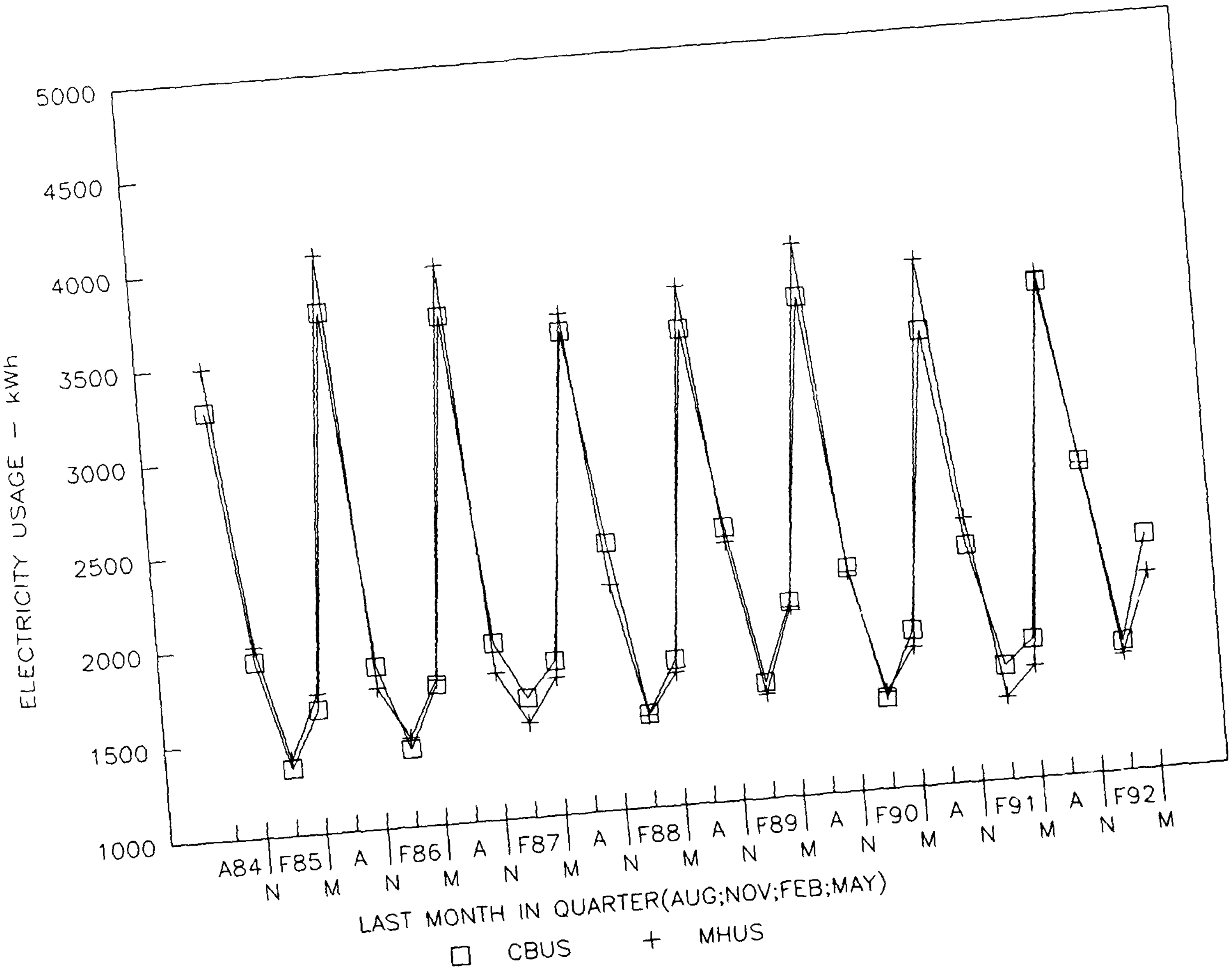


Figure 8. Quarterly electricity consumption.

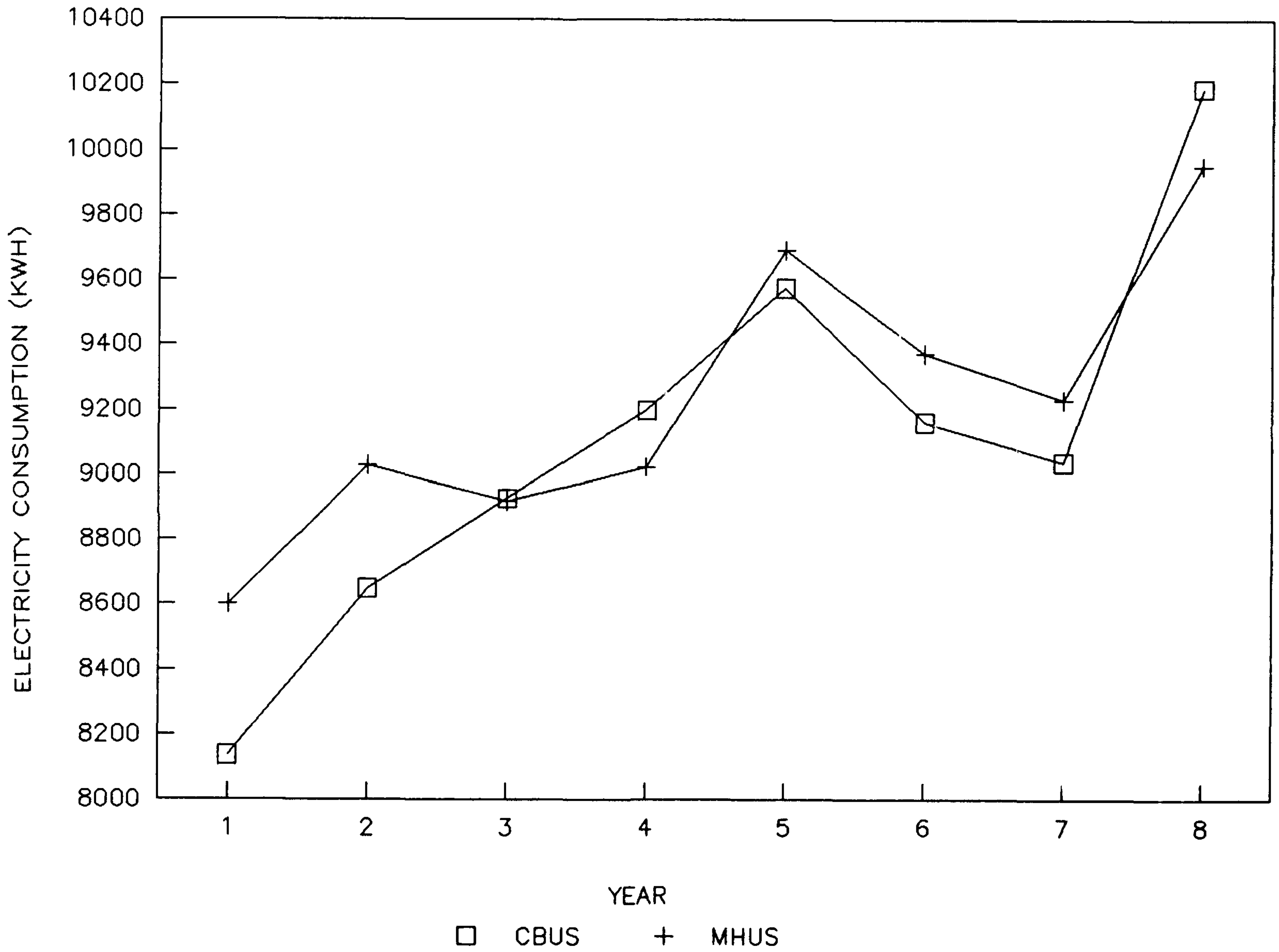


Figure 9. Yearly electricity consumption.

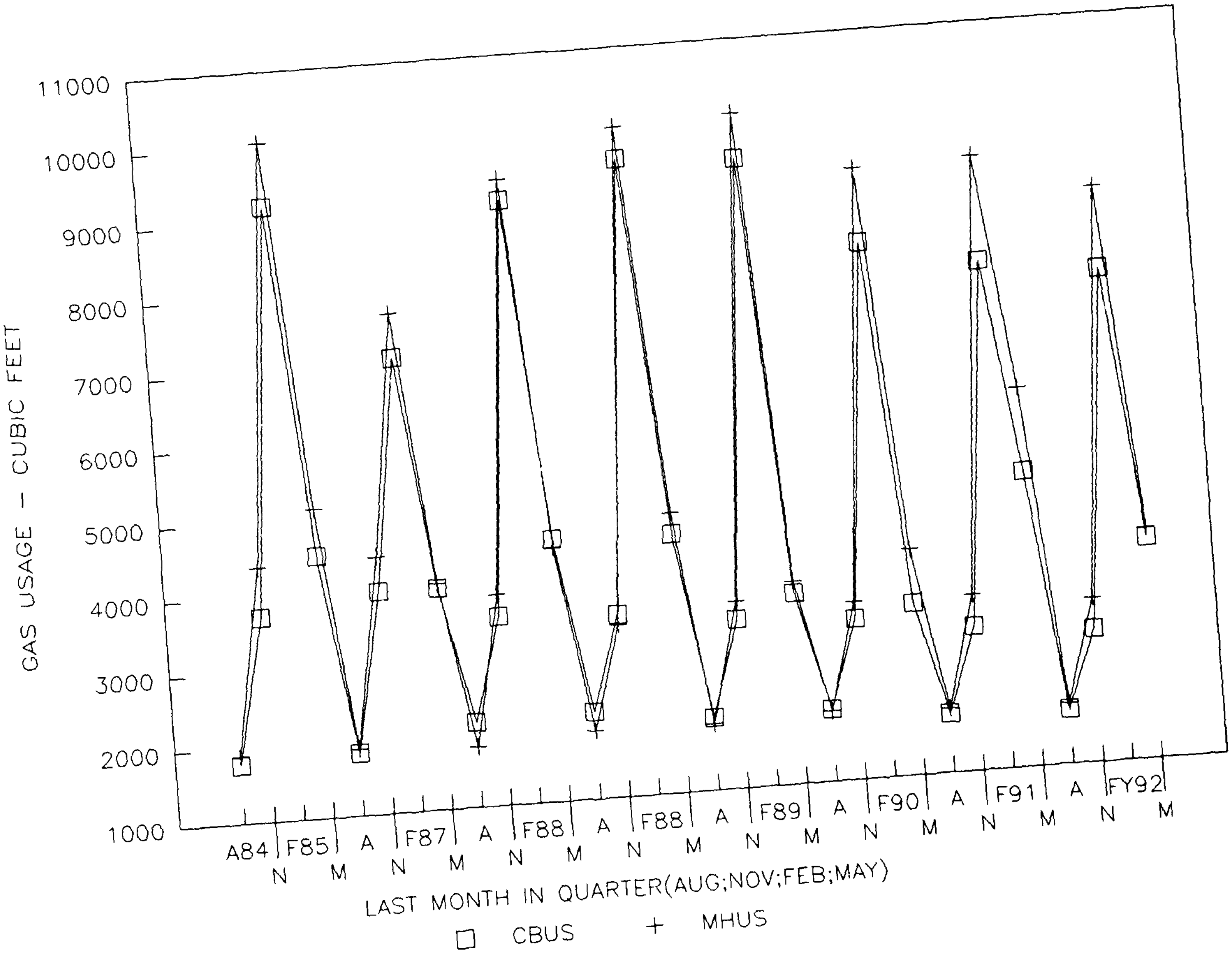


Figure 10. Quarterly gas consumption.

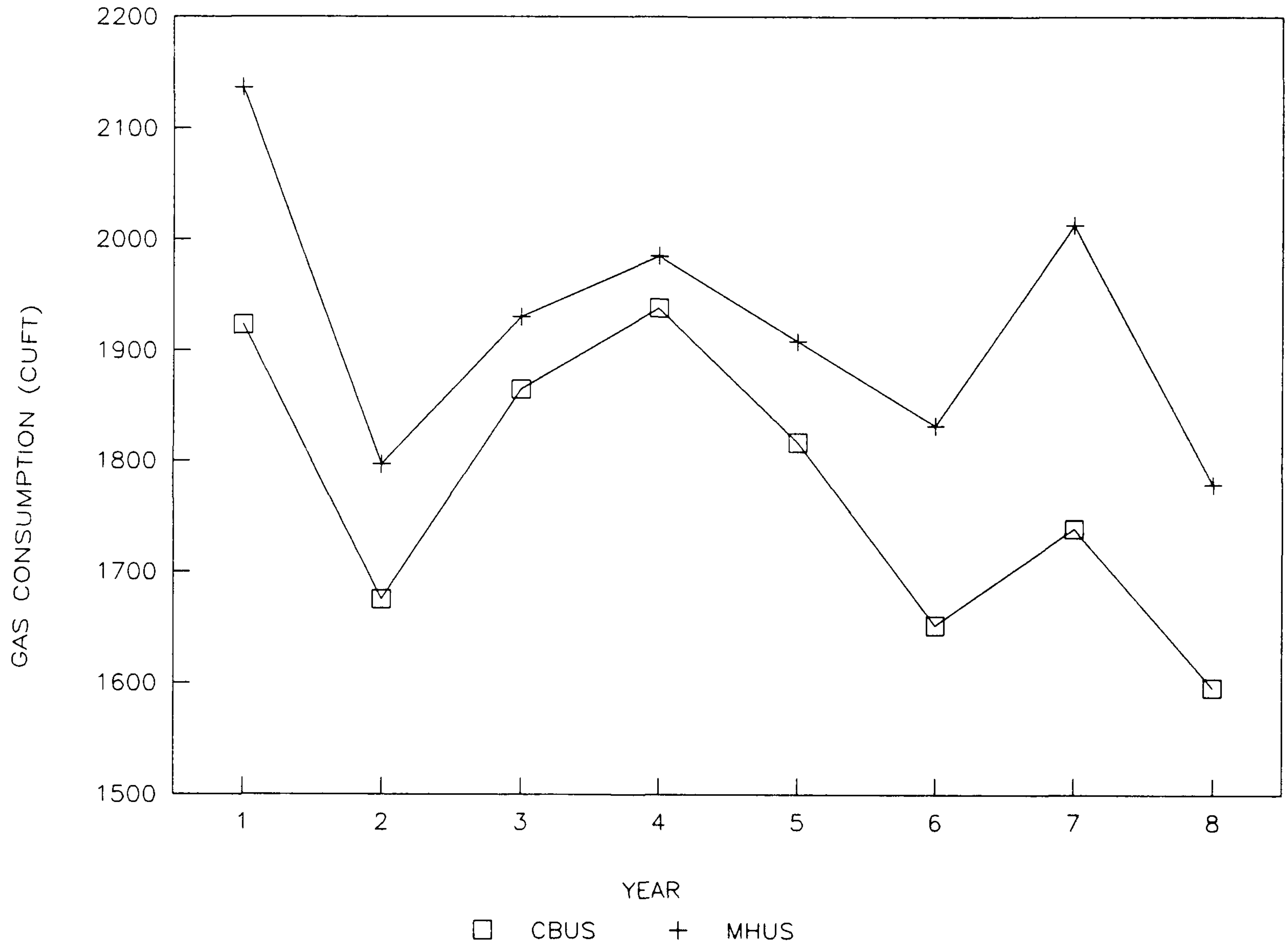


Figure 11. Yearly gas consumption.

8 CONCLUSIONS AND RECOMMENDATIONS

Maintenance Costs

After 8 years' occupancy, there is a significant difference in maintenance costs between the two types of units. For all 8 years, the MHUs cost $198 more per unit for maintenance (ignoring equipment costs, such as ranges and dishwashers). This is a 45.6 percent difference in costs ($632/year for MHU vs $434/year for CBU, Table 5). For year 8, the difference is $555 or 119 percent ($1019 for MHU vs $466 for CBU).

Energy Costs

MHUs cost more than CBUs for energy used—$28 more per unit per year for gas and electricity.

Water Piping

The MHU water piping is being replaced. Piping failures are not only significantly increasing the cost, but also are affecting the morale of families in units with major problems. There is a very significant difference to the government in costs between the two types of construction due to this problem.

It is recommended data collection continue for 1 more year.

APPENDIX A: Description of the MHU Construction Process

The MHUs were not typical of manufactured housing in that the manufacturer was not allowed to design the housing. The contractor was given designs based on the fourplexes being built using conventional construction methods and was required to manufacture accordingly. Thus, it is possible that given the opportunity to both design and manufacture, the final structure might be somewhat different and less costly.

The concept used was to manufacture complete modules in the factory, which could be transported (about 200 miles from the factory in the Los Angeles area to Fort Irwin) and assembled on site. Thus, the process involved several steps: manufacture of complete modules (electrical, plumbing, HVAC, etc., included at the plant); construction of perimeter footings at the site; transportation of modules to the site; assembly of the modules into fourplexes using a crane; joining modules together including connection of piping and electrical wiring; application of stucco exterior finish; roofing at the module joints and securing of eaves; and on-site construction of the garages. On-site construction was limited by contract to foundations, utilities, slabs, garages, exterior finishes, final painting, exterior stairways and balconies. Figures A1 through A6 show factory work, modules on trucks, crane assembly and a completed fourplex without stucco and garages.

The eaves were attached using flat metal straps and folded onto the roof for transportation (this decreased the width for highway transportation). Upon assembly at the site, the eaves were folded down and secured with only a few nails. This was a defect in the design/construction, as the eaves began to loosen; one fell to the ground. All eaves were then permanently secured at a cost of over $300,000 ($6000 per building).

The MHUs are essentially the same as the CBUs; floor plans of the two types are very similar. Figures A7 through A10 show sample floor plans for the MHUs and the CBUs.

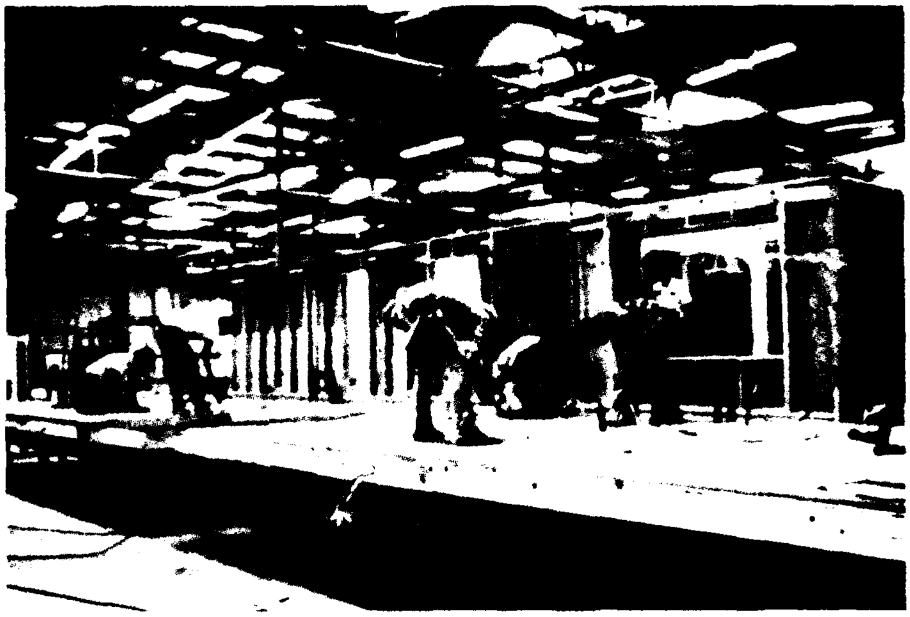


Figure A1. Construction in the factory.

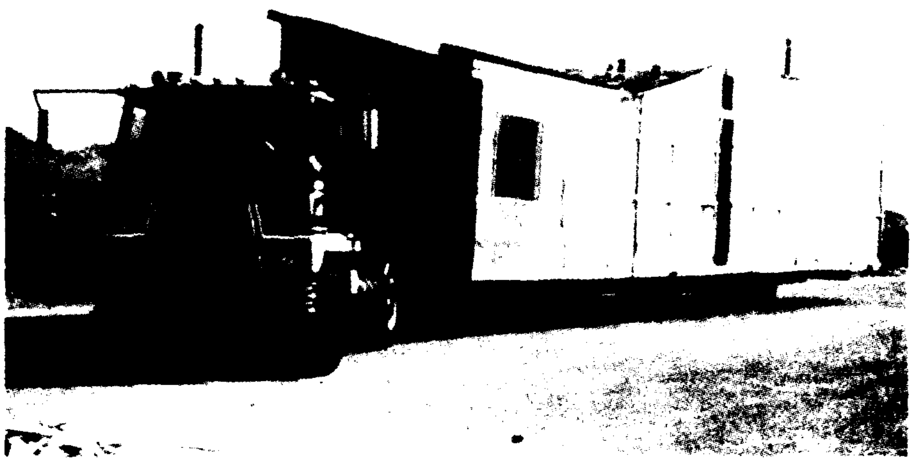


Figure A2. Two modules loaded on truck.

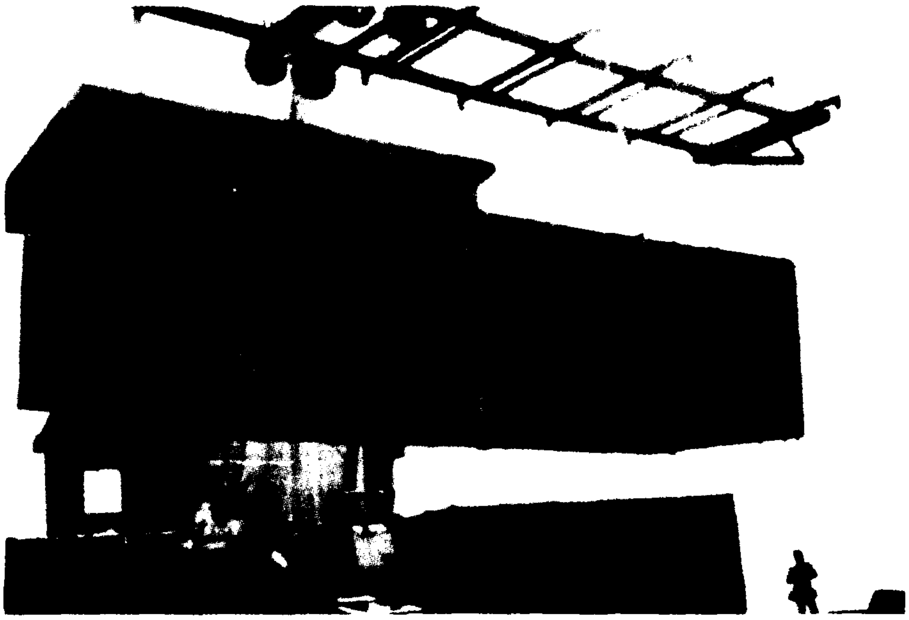


Figure A3. Module being set in place by crane.

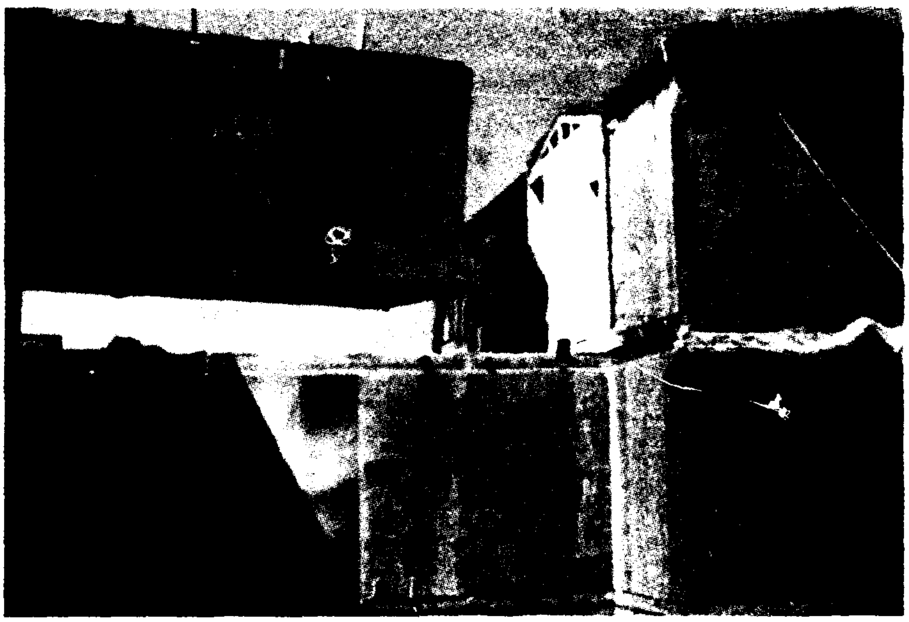


Figure A4. Near completion of one building.

Figure A5. Completed assembly of modules.

Figure A6. Overview of buildings without garages.

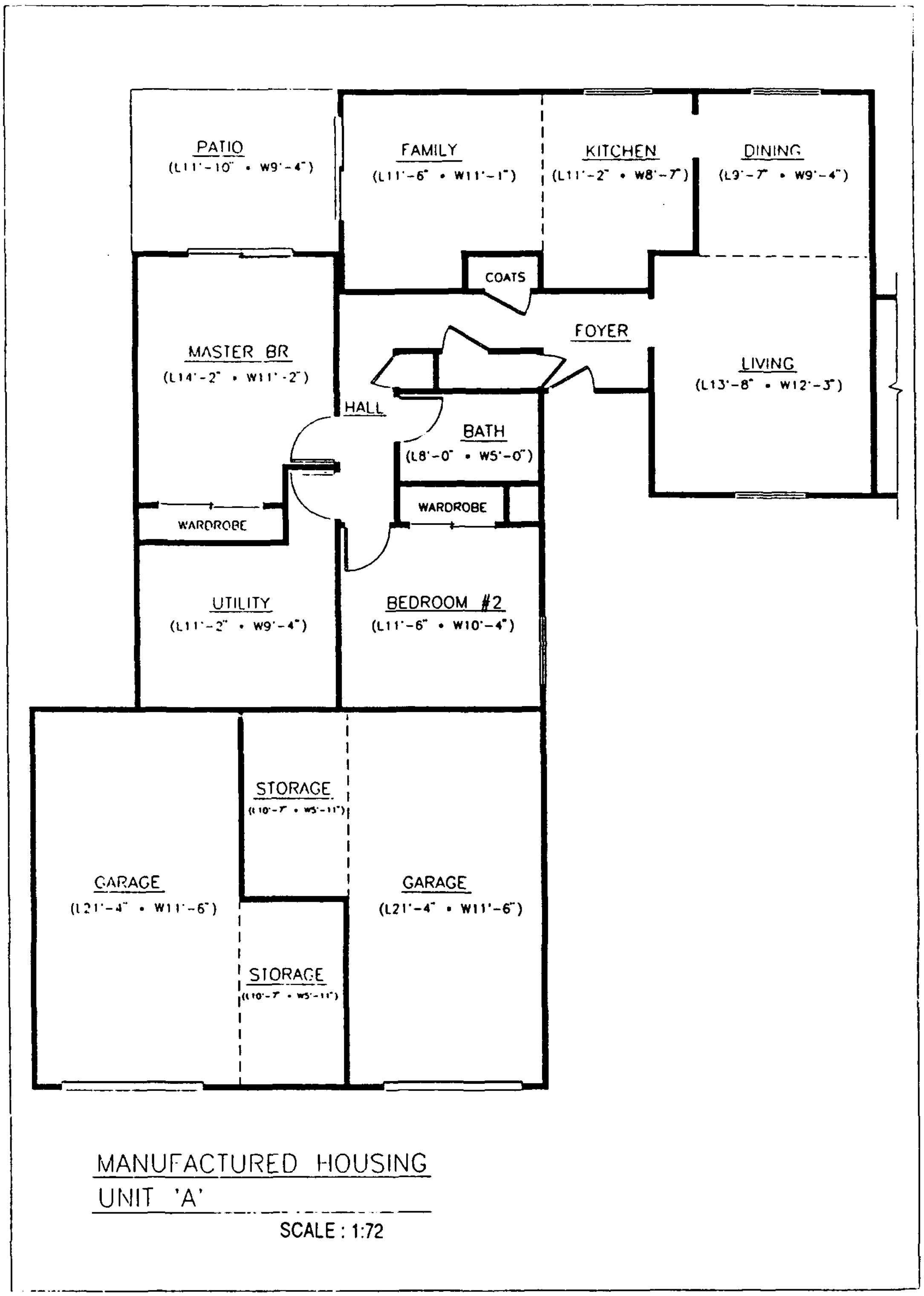


Figure A7. Floor plan for first floor MHU, Type A.

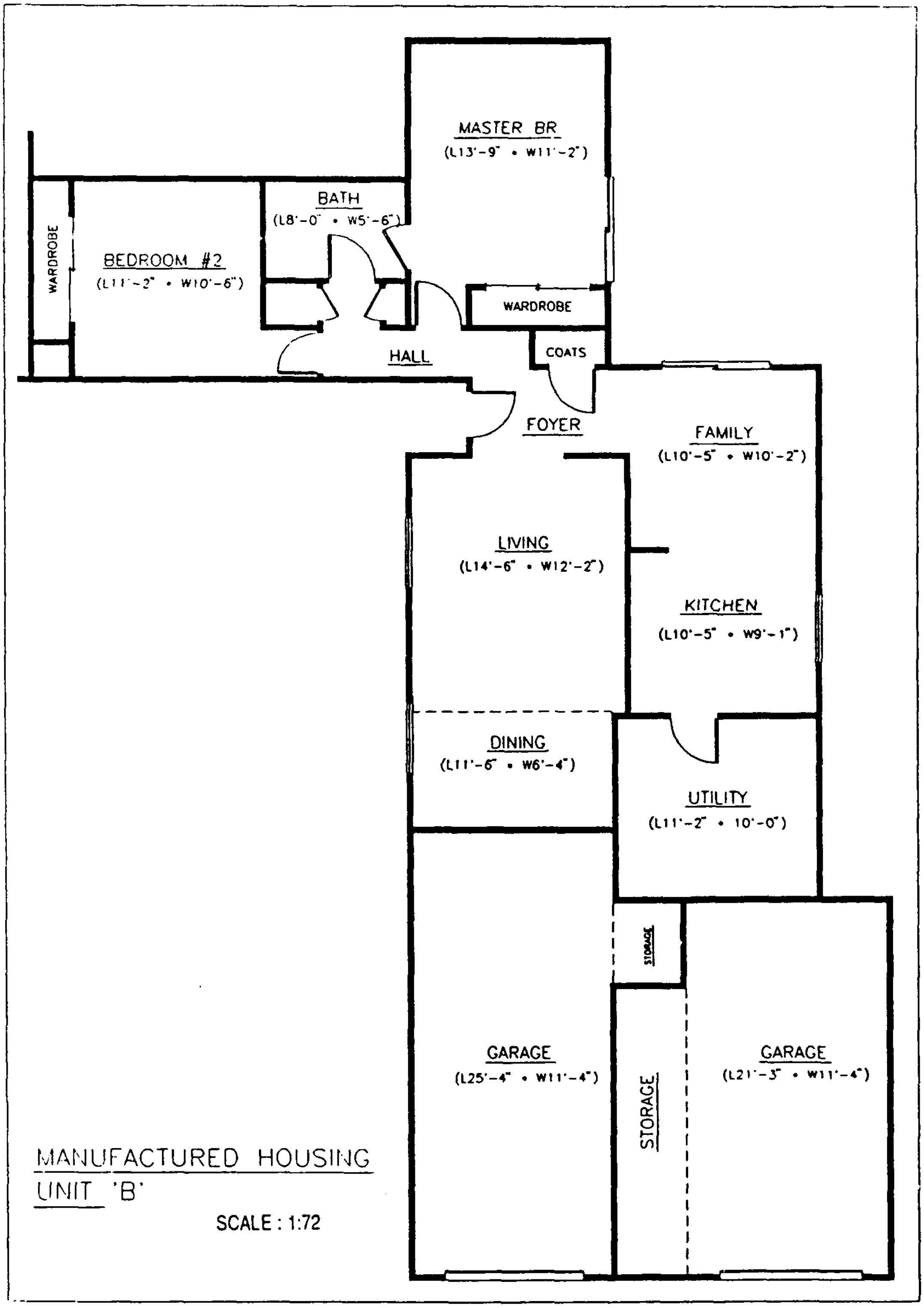


Figure A8. Floor plan for first floor MHU, Type B.

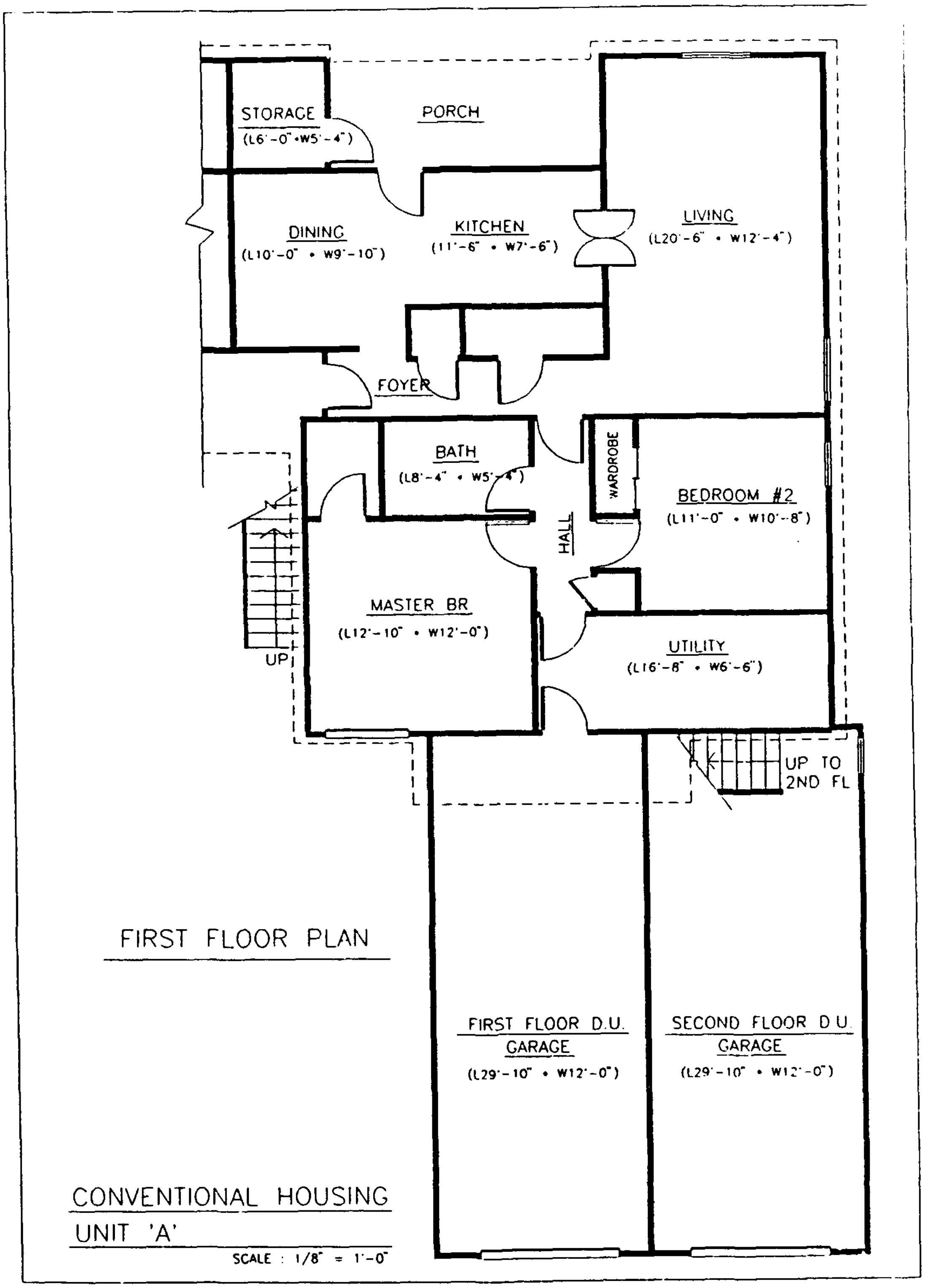


Figure A9. Floor plan for first floor CBU, Type A.

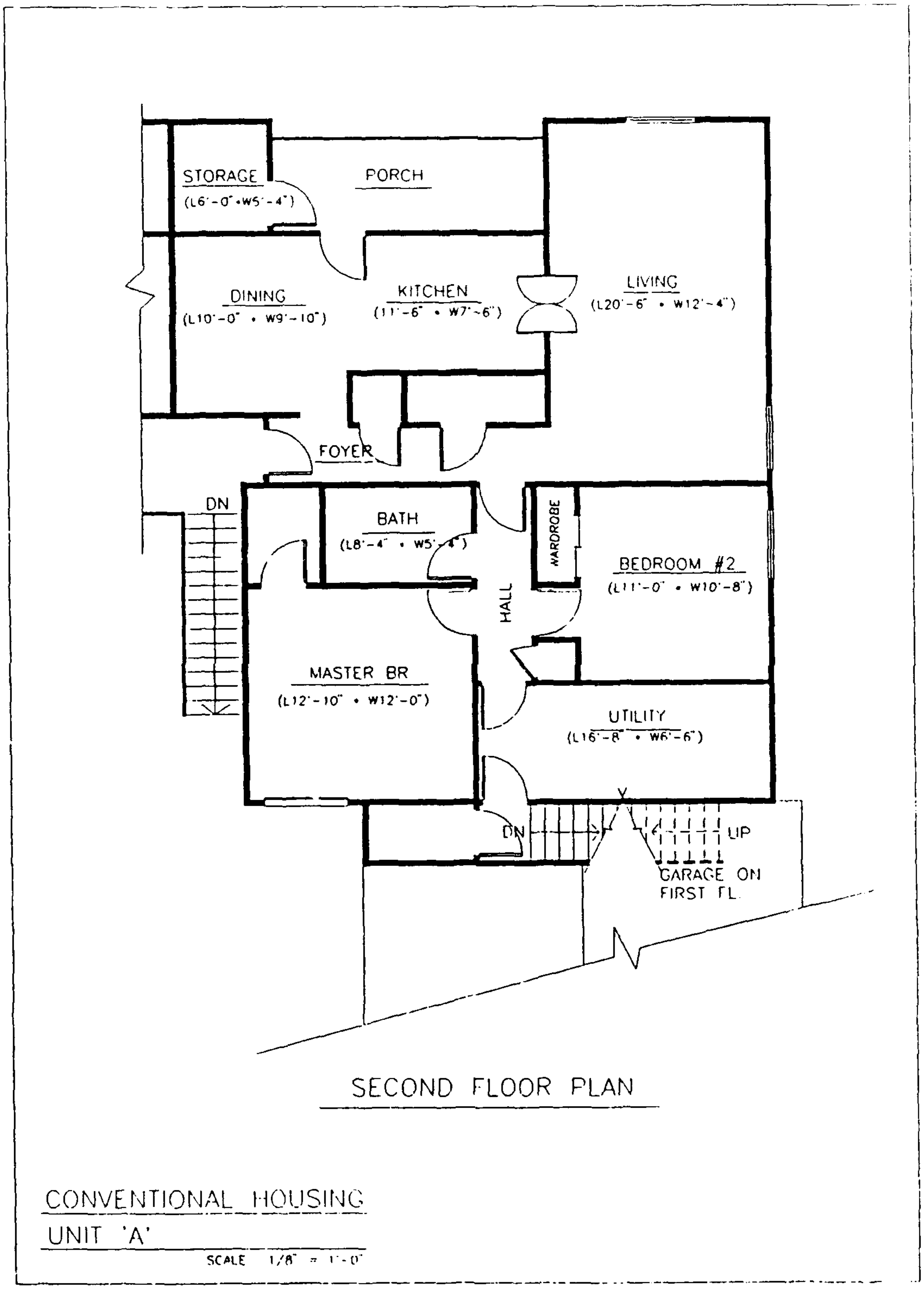


Figure A10. Floor plan for second floor CBU, Type A.

APPENDIX B: List of Housing Units

Conventionally Built

3680 A-F	3705 A-E	3727 A-E
3681 A-D	3712 A-F	3731 A-D
3684 A-D	3715 A-F	3732 A-F
3685 A-F	3720 A-F	3738 A-F
3690 A-F	3721 A-E	3742 A-D
3691 A-D	3722 A-E	3743 A-F
3693 A-F	3723 A-E	3745 A-F
3694 A-D	3724 A-D	3747 A-D
3695 A-D	3725 A-E	3750 A-F
3700 A-F		

Manufactured (Each with four apartments, A-D)

3800	3821	3841
3801	3822	3842
3802	3823	3843
3803	3824	3844
3804	3825	3845
3805	3826	3846
3806	3827	3848
3807	3828	3850
3809	3829	3851
3811	3831	3852
3812	3832	3853
3813	3833	3854
3814	3834	3855
3815	3835	3856
3816	3837	3857
3818	3839	3858
3820	3840	

APPENDIX C: Building Component/Subcomponent Codes

01 Roofing

0101	Roofing surface
0102	Fasteners
0103	Flashing, vents, protrusions
0104	Gutter and downspouts
0105	Other roof repairs

02 Structure

0201	Foundation and anchorage
0202	Structure, incl. framing and sheathing, stairs, cracked wall
0203	Insulation and moisture protection
0204	Masonry
0205	Exterior siding, incl. skirting
0206	Exterior doors and frames, incl. hardware and weatherstripping
0207	Storm and screen doors
0208	Window and frames, incl. hardware and weatherstripping
0209	Storm windows and screens
0210	Exterior trim
0211	Porch/deck construction
0212	Interior drywall, incl. fasteners and accessories
0213	Wall coverings and paneling
0214	Interior doors, frames, and hardware, incl. bifold and sliding
0215	Interior casework and finish carpentry
0216	Bathroom accessories, mirror
0217	Kitchen accessories, cabinets
0218	Drapery hardware
0219	Other exterior/interior repair, venetian blinds
0220	Garage door

03 Floor Coverings

0301	Resilient flooring
0302	Carpet and pad
0303	Ceramic flooring
0304	Underlayment/substrate
0305	Other flooring repairs

04 Interior Painting

0401	Walls and ceilings, incl. patching
0402	Trim
0403	Touch-up
0404	Bathtub/shower unit caulking
0405	Other Interior painting

05 Exterior Painting

0501	Walls, siding, incl. skirting
0502	Doors, frames, trim
0503	Exterior trim, incl. window, fascia, rake, soffit, etc.
0504	Caulking and sealing
0505	Glazing
0506	Other exterior painting

06 Heating

0601	Heating plant, valve
0602	Motors, blowers, pumps, G-60
0603	Ducts
0604	Piping
0605	Diffusers, grills
0606	Insulation
0607	Heating controls
0608	Other heating repairs, instructions for thermostat, turn on gas

07 Air Conditioning

0701	Cooling coils, compressor, condenser, valve, contactor
0702	Motors, blowers, pumps, transformer, fuses
0703	Piping, ducting
0704	Refrigerant
0705	Insulation
0706	Controls, delay module, relay
0707	Other cooling repairs, instruct thermostat use, filter

08 Plumbing

0801	Water heater
0802	Water softener
0803	Piping, supply, incl. valves, arrestors
0804	Faucets and shower heads
0805	Lavatories, incl. support and fasteners, caulking
0806	Water closets (i.e., toilets and commodes), incl. support and seals, caulking
0807	Bathtub/shower unit
0809	Other plumbing repair

09 Electrical

0901	Service entrance
0902	Panel box, incl. circuit breakers
0903	Branch circuits, incl. junctions, fasteners
0904	Wall receptacles and switches

0905	Doorbells, chimes
0906	Light fixtures
0907	Vents, fans
0908	Other electrical repair

10 Equipment

1001	Disposal
1002	Dishwasher
1003	Stove, range
1004	Range hood
1005	Refrigerator
1006	Other equipment

11 Utility Plant Equipment

Not applicable

12 Utility Service

1201	Water supply
1202	Gas supply
1203	Electrical service
1204	Sanitary/sewer
1205	Other utility service

13 Miscellaneous

APPENDIX D: Energy Efficiency Tests of 15 Conventionally Built Housing Units

The objective of these tests was to provide data concerning the energy efficiency of conventionally built housing. Tests were performed to determine the airtightness of the units (a measure of the resistance to air infiltration), furnace efficiencies, and heat transfer characteristics of the building envelope.

I. Tests Performed Upon Completion of Construction

Tests were conducted over 4 days in June 1983 on three types of buildings: a fourplex, a fiveplex, and a sixplex. Weather conditions were typical of the high desert area: light to negligible winds, clear skies, low humidity, and temperatures ranging from lows near 70 °F to highs near 110 °F.

House Tightness

A blower door apparatus was used to measure each unit's tightness. The blower door consisted of a variable speed fan, a digital tachometer to measure the fan blade rotation speed, and an inclined manometer to measure pressure differences. The fan could be operated to induce a positive or negative pressure difference in the house with respect to the outdoors.

To perform this test, the fan was fitted tightly into an outside door frame. A barbed fitting that penetrates the blower door was fitted with rubber tubing and connected to one side of the manometer. The other side of the manometer was open to the house. When the fan was operated, it could either force air into the house (pressurized) or force air out of the house (depressurized) depending on the direction of rotation. In either case, the pressure difference between the house and the outdoors could be read on the manometer. The fan speed was adjusted until a specified pressure difference existed (usually 0.1 or 0.2 in. of water). The fan speed required to achieve a given pressure was correlated to air flow, which indicated how tightly the house was sealed.

Each of the units was tested at 0.1 and 0.2 in. H_2O pressurized, and 0.2 in. H_2O depressurized. Some of the more obvious leaks (furnace room doors, dryer vents, attic doors) were then taped, and the house was again tested at 0.2 in. H_2O depressurized.

As shown in Table D1, airtightness was adequate, requiring no corrective work.

Furnace Efficiency

The furnaces in all the units were propane-fired. Tests were performed with a Fuel Efficiency Monitor (FEM), a hand-held automatic flue gas analyzer that measures the flue gas temperature, oxygen content, and ambient conditions and uses this information to calculate and display the percent efficiency of the furnace.

Each housing unit was first cooled down to allow the furnace to operate. The thermostats in the houses were of the "energy-saving" type, and included night setback and temperature limits. These were disconnected before each test so that the heating and air conditioning could be manually adjusted. The safety relief on the front of each furnace was covered so that room air would not be introduced into the flue. The furnace was then turned on, and a sample was taken of the intake air using the FEM. A 1/8-in.

Table D1

CBU Energy Efficiency Data After Construction

Building/Unit	UA* Btu/Hr-°F	No. Air Changes** Per Hour	Furnace*** Efficiency (%)
3720A	213	11.4	52.6
3720B	181	12.1	61.3
3720C	181	13.1	62.8
3720D	213	12.8	67.2
3720E	304	12.4	71.7
3720F	304	13.2	73.0
3724A	181	11.8	61.9
3724B	181	13.3	62.6
3724C	304	13.0	71.4
3724D	304	15.1	72.3
3725A	181	11.7	61.6
3725B	181	12.8	****
3725C	213	13.9	69.3
3725D	304	13.4	72.7
3725E	304	14.8	****

*These are calculated values based on the wall construction. U=heat transfer; A = area
**The following rating of air changes per hour at 0.2in. water column is based on work currently being done by Mansville Corp. for the U.S. Navy; 0 to 5, objectively tight; 5 to 10, excellent; 10 to 15, satisfactory; 15 and above merits corrective work.
***Most gas fired furnace manufacturers claim 80 percent efficiency.
****Unable to test furnace due to lack of access to the units.

hole was then drilled in the flue of the furnace. After allowing a few minutes for the furnace to reach steady state, the FEM probe was inserted into the flue pipe and a sample was taken of the exhaust gas. The FEM took 2 to 3 min to calculate the furnace efficiency. Table D1 shows the furnaces' operational efficiencies.

Wall Heat Transfer Characteristics

A Thermo Flow Energy Meter (TEM) was obtained to test the heat transfer characteristics of the walls. The TEM is an infrared radiometer that displays heat flow digitally in units of Btu/hr/sq ft. It can be used to detect insulation defects and to estimate the thermal resistance of exterior walls.

Due to unfavorable weather, the TEM could not be used to calculate R-values. The device was also useful for detecting insulation voids. No insulation voids were found.

II. Tests Performed after 5 Years' Occupancy

The house tightness and furnace efficiency tests were performed again in May 1988. Results are summarized below in Table D2. Again, no wall insulation tests were performed because of weather conditions.

Table D2

CBU Energy Efficiency Data 5 Years After Construction

Unit No.	No. Air Changes Per Hour	Furnace Efficiency (%)
3720A	11.0	58.5
3720B	11.4	68.6
3720C	12.9	65.8
3720D	10.2	70.6
3720E	10.6	74.2
3720F	10.8	59.5
3724A	10.6	68.9
3724B	11.6	57.8
3724C	14.4	67.4
3724D	12.3	70.4
3725A	11.3	66.0
3725B	11.8	24.1
3725C	14.4	68.8
3725D	16.2	67.3
3725E	12.4	74.5

APPENDIX E: Energy Efficiency Tests of 16 Manufactured Housing Units

The objective of these tests was to provide data on the energy efficiency of manufactured housing units for comparison to existing energy efficiency data taken on conventionally built housing units. Tests were performed to determine the airtightness of the units (a measure of the resistance to air infiltration), furnace efficiencies, and heat transfer characteristics of the building envelope.

I. Tests Performed Upon Completion of Construction

Tests were conducted on three types of fourplexes; Type I (Building 3809), II (Building 3802), and IV (Buildings 3800 and 3806). The tests were conducted over 4 days in April 1984. The weather during the testing was mild for high desert area; medium to strong winds, overcast skies, low humidity, and temperatures ranging from morning lows of 40 °F to highs near 80 °F.

House Tightness

To measure the tightness of each housing unit a blower door apparatus was used, as described in Appendix D.

Each of the manufactured housing units was tested at 0.1, 0.2, and 0.3 in. of water during pressurization and then tested at 0.1 and 0.2 in. under depressurization. Then air leaks were taped (furnace doors and kitchen vents) and the unit was retested at 0.2 in. during pressurization. During the final day the winds were gusting so high that no consistent manometer reading could be taken, so Building 3809 had no data for air infiltration.

The results of the USACERL testing, as presented in Table E1, demonstrate that the airtightness of all the units except one is acceptable. Unit 3800-C had a significantly higher value than the other units and should have corrective work done to improve its tightness.

During the airtightness testing, several leaks were found. In Type II, Unit 3802-C, serious leaks were found in the door to the furnace room. In Type IV, Units 3800 and 3806, leaks were found while depressurizing around the furnace vents and doors (Unit A in both buildings). Also, leaks were found around sliding doors (Unit 3800-C), kitchen window area (Unit 3806-D), utility outlets (Unit 3800-D), and a crack in the dining room wall (Unit 3806-D).

Furnace Efficiency

The furnaces in all of the units were propane-fired. Tests were performed using a FEM, as described in Appendix D. A carbon monoxide meter similar to the FEM was used to ensure that each furnace's burner was completely combusting its fuel and that there was no unusual concentration of carbon monoxide.

Table E1

MHU Energy Efficiency Data After Construction

Building/Unit	UA* Btu/Hr-°F	No. Air Changes Per Hour	Furnace Efficiency (%)
3800A	296	9.9	75.5
3800B	296	11.5	81.8
3800C	363	18.4	80.5
3800D	363	11.3	82.6
3802A	271	9.0	70.1
3802B	271	10.1	75.1
3802C	370	12.1	81.8
3802D	370	11.3	80.3
3806A	296	8.0	78.2
3806B	296	9.8	77.4
3806C	363	8.7	80.7
3806D	363	10.6	82.2
3809A	249	**	80.0
3809B	249	**	82.0
3809C	336	**	80.7
3809D	336	**	79.6

*These are calculated based on the wall construction. U = heat transfer coefficient; A = area.
**Unable to test airtightness due to high winds.

The testing was performed in the early morning hours so there would be a low outdoor temperature to start the furnace. The safety relief on the front of each furnace was taped over to prevent room air from entering the flue. A 1/8-in. hole was drilled into the flue near the furnace. The furnace was turned on and a sample of the ambient air was taken. The furnace was then left to reach steady state (approximately 15 min) and then the FEM probe was inserted into the hole and a sample of the exhaust gas was taken. The FEM took approximately 2 to 3 min to calculate and display the efficiency. Three samples were taken to ensure furnace steady state. The hole in the flue was then taped closed.

The furnace efficiencies are typical for the size and type of furnace installed.

Wall Heat Transfer Characteristics

A TEM, as described in Appendix D, was used to test the heat transfer characteristics of the exterior walls of each unit and to detect insulation defects.

This testing was done in the early morning hours because there must be a constant temperature difference of at least 20 °F between outdoor and indoor temperatures. First the outdoor and indoor

temperatures were taken until they appeared steady. The TEM was then aimed at an interior wall and the net heat flow reading was recorded. Then the TEM was aimed at an exterior wall and the heat flow through the wall was recorded. Finally, the same measurement was made on the outside of the exterior wall (being sure that the area was shaded from sunlight). These results were used in conjunction with a standardized chart to determine the wall's thermal resistance. After these measurements were taken, the TEM was used to detect areas of high net flow readings, which indicate areas of insulation defects. There appear to be a number of insulation voids in Type I, II, and IV Units.

The UA values were calculated for the units, representing the overall heat transfer for the unit inclusive of walls, windows, doors, and roof (heat transferred from one unit to the next unit was considered negligible). The insulation voids listed in Table E2 were determined when the net heat flow varied by 10 Btu/hr-°F.

II. Tests Performed After 5 Years' Occupancy

The house tightness and furnace efficiency tests were performed again 5 years after construction. Results are given in Table E3.

Table E2

Insulation Void Locations

Building/Unit	Location of Void
3802A	Void area at upper left corner of window in front bedroom.
3802C	Void area above sliding glass door in dining room.
3802D	Void area at right electrical outlet in dining room.
3806C	Void areas in all wall-to-wall seams (corners).
3806D	Void areas in all wall-to-wall seams (corners).
3809B	Void area at upper right corner of sliding glass door in dining room.

Table E3

MHU Energy Data 5 Years After Construction

Building/Unit	No. Air Changes Per Hour	Furnace Efficiency (%)
3800A	7.8	75.9
3800B	9.4	80.2
380c0	*	76.3
3800D	10.2	72.8
3802A	9.6	71.2
3802B	10.2	80.4
3802C	10.8	79.1
3802D	*	*
3806A	8.6	79.9
3806B	10.3	77.1
3806C	11.4	79.8
3806D	12.9	76.6
3809A	7.4	78.7
3809B	7.0	73.9
3809C	10.2	79.2
3809D	10.3	78.3

APPENDIX F: CERL Letter Report "Summary of Findings for Fort Irwin Polybutylene Pipe Failure," to U.S. Army Engineering and Housing Support Center, Dated 30 September 1992

DEPARTMENT OF THE ARMY
CONSTRUCTION ENGINEERING RESEARCH LABORATORIES, CORPS OF ENGINEERS
P.O. BOX 9005
CHAMPAIGN, ILLINOIS 61826-9005

REPLY TO ATTENTION OF:

30 SEP 1992

CECER-FM (70-1y)

MEMORANDUM FOR Commander, U.S. Army Engineering and Housing Support Center, ATTN: CEHSC-HM-O (Alex Houtzager), Ft. Belvoir, VA 22060-5580

SUBJECT: Summary of Findings for Ft. Irwin Polybutylene Pipe Failure

1. The U.S Army Construction Engineering Research Laboratories was tasked to conduct a failure analysis of the Polybutylene plastic water pipes in the manufactured housing at Ft. Irwin, CA to determine the cause of the failures, evaluate CEGS 15400 and other Corps specifications to determine whether changes are needed to preclude the problem reoccuring, and to fully document the pipe replacement in building 3804 at Ft. Irwin. The funding to do the work was authorized by FAD No. 92-080020 dated 10 August 1992.

2. Enclosure (1) is a Summary of Findings which documents the piping replacement of building 3804 at Ft. Irwin, provides an analysis of the cause of the pipe failures and makes recommendations for changes to CEGS 15400.

3. A copy of this memorandum and attachments will be sent to Mr. Ron Randolf at the South Pacific Division, as well as Mr. Walt Perry at Ft. Irwin.

4. If you have any questions or comments I can be contacted at FTS or Commercial (217) 373-6766.

Encl

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SUMMARY OF FINDINGS

Ft. Irwin Polybutylene Pipe Replacement

1. STATEMENT OF PROBLEM:

In 1982 and 1983 the Corps of Engineers built 144 stick built apartment units and 200 manufactured housing units at Ft. Irwin, CA. The manufacturer of the 200 housing units used national standards in the unit construction which included the use of polybutylene (PB) piping. The piping was installed by the manufacturer in the planet in Southern California and connections were made by the contractor when the building modules were assembled at Ft. Irwin.

Once the manufactured housing was in place and being used, an exceptionally high number of leaks primarily in the hard plastic tees and valves, occurred. The number of leaks began at a low rate but as time has passed, they have been occurring at an ever increasing rate. A memorandum report (Appendix A) addressing the dramatic increase in the plumbing leaks and the associated cost of making the repairs was prepared in August 1991 by USACERL. The manufactured housing plumbing repair costs over a seven year period was 268% higher than the stick build housing units.

Ft. Irwin, in an effort to reduce the plumbing maintenance and repair costs, wants to replace the plumbing in the manufactured housing units at an estimated cost of $2M. A contract was awarded to do one building in order to develop the methods and to develop a better estimate of the overall cost to do the entire work.

2. SCOPE:

The scope of this report is limited to the documentation and observation of the pipe replacement in building 3804 at Ft. Irwin, CA. Also included are conclusions as to the causes of failure of the polybutylene plastic water pipes in the manufactured housing at Ft. Irwin, and recommendations for guidance changes associated with the use of that particular plumbing system.

3. PIPE REPLACEMENT:

The pipe replacement was accomplished under Work Order No. ER00 140 -1 dated 5 July 1991. The final negotiated price for performing the work was $42,898.42. Appendix B is a copy of the Statement of Work. The work began on 9 March 1992 and was completed 1 May 1992.

The work originally consisted of removing the polybutylene plumbing in building 3804 and replacing it with type M copper and chlorinated polyvinyl chloride (CPVC) plumbing. Once the new plumbing was in place, the contractor was also required to disinfect the new piping system and to perform a water pressure test of the replacement plumbing.

Ft. Irwin maintains two separate potable water distribution systems, one for drinking water and the other for general use. The drinking water is treated in a reverse osmosis purification system and the resulting water is corrosive to copper piping. CPVC plumbing was installed in place of polybutylene to carry the drinking water. The water for other uses will not normally corrode copper so it was selected for replacement of the remainder of the polybutylene plumbing system.

Once the work began, it was discovered that the old, in-place plumbing did not correspond well with the as-built drawings in many instances. The contractor spent one day locating and tracing the old plumbing. Some of the differences noted were (1) the as-built drawings indicated that all the pipes were hung in the ceilings of the downstairs housing units when in fact they were laid in just under the sub-flooring for both first and second story units, (2) the as-built drawings indicated that all the pipes were hung in notches at the bottom of the second story floor joists or the top of the first story ceiling joists (Figure 1) when in fact they were laid in in notches just under the sub-flooring for each housing unit (Figures 2 and 3), and (3) the locations of the plumbing track runs varied by several feet from what was depicted.

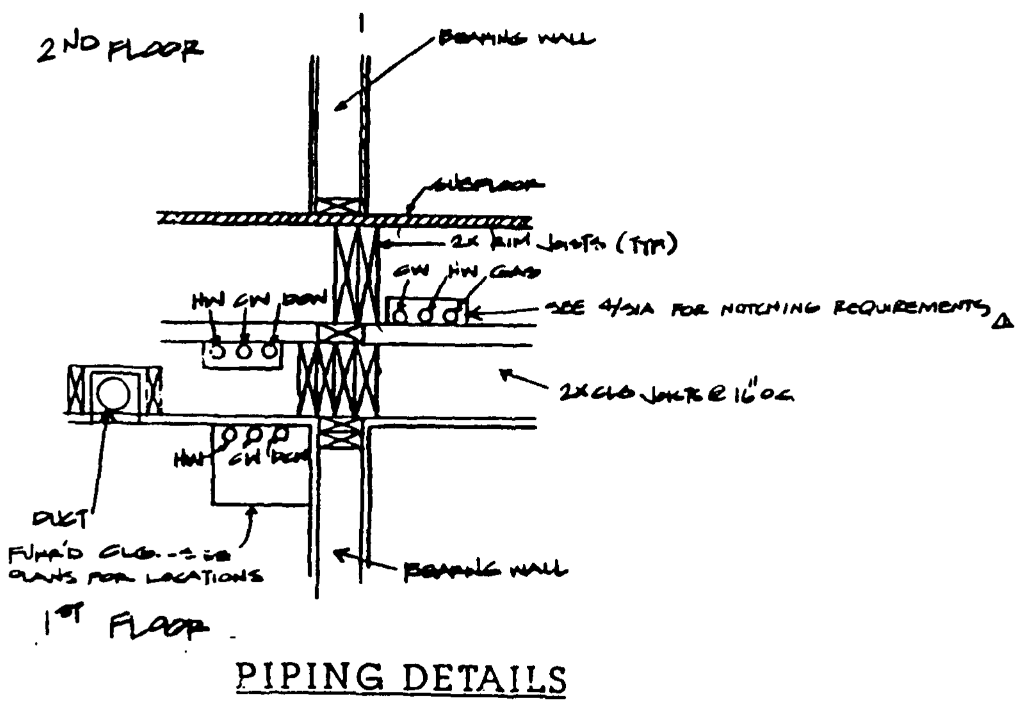


Figure F1: Piping Detail from As-Built Drawings

Figure F2: Plumbing run in crawl space under Unit A

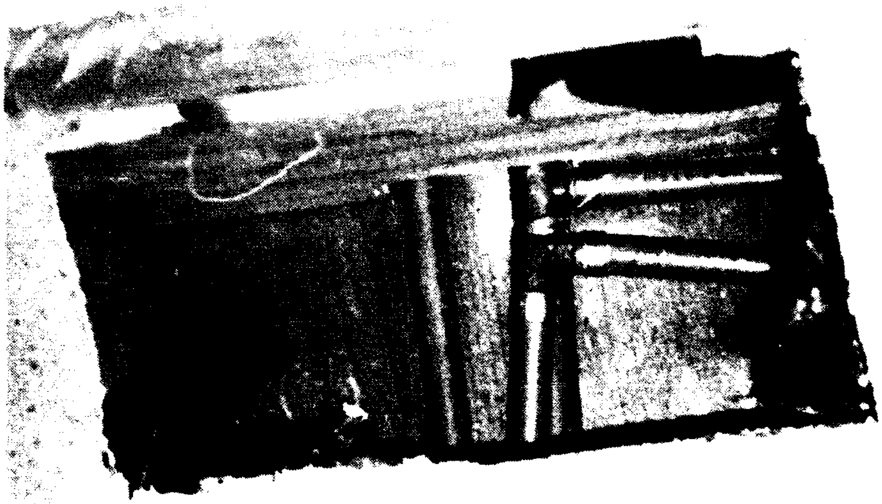


Figure F3: Plumbing in ceiling of Unit A for Unit B

Since the polybutylene pipes were installed directly under the sub-flooring, in order to gain access to them above the air plenum in the downstairs apartments, three different layers of sheet rock needed to be removed in the hallway (Figures 4 and 5) and two in the kitchen. The Ft. Irwin DEH, as a result, allowed the contractor to abandon in-place the polybutylene plumbing that was under the sub-floors. In addition, the contractor was allowed to use flexible copper tubing (Figure 6) to go around ventilation conduit in the downstairs bathroom ceiling, for the upstairs sink and for uprights to the bath tub faucets. It was discovered that replacing the polybutylene riser from the bathtub faucets to the shower head would require breaking a hole in the outside exterior wall and would also require removing the electrical service junction boxes to gain access to it (Figure 7). Therefore, that section of polybutylene pipe (Figure 8) and associated acetal fittings were not replaced.

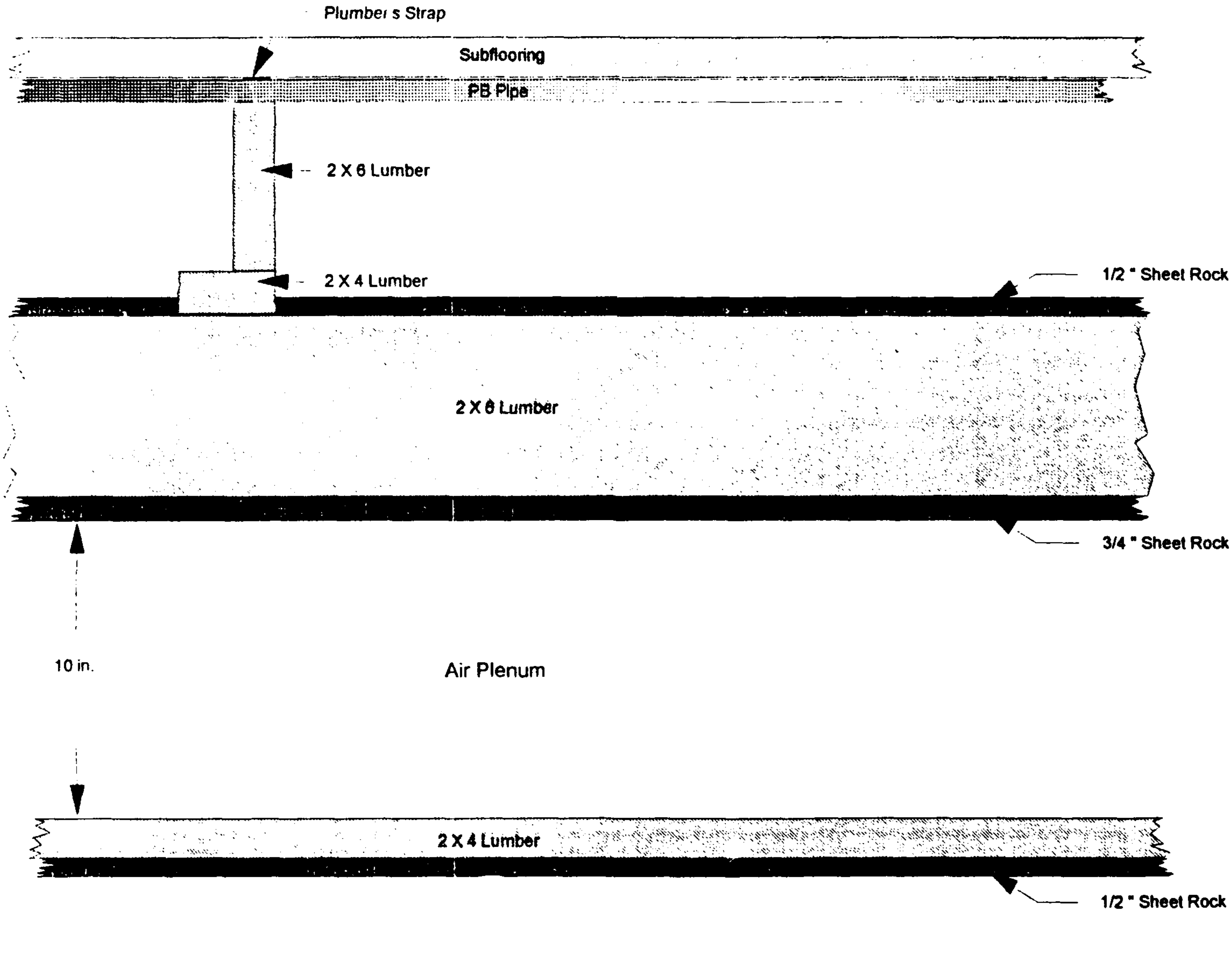


Figure F4: Drawing of Piping Over Air Plenum

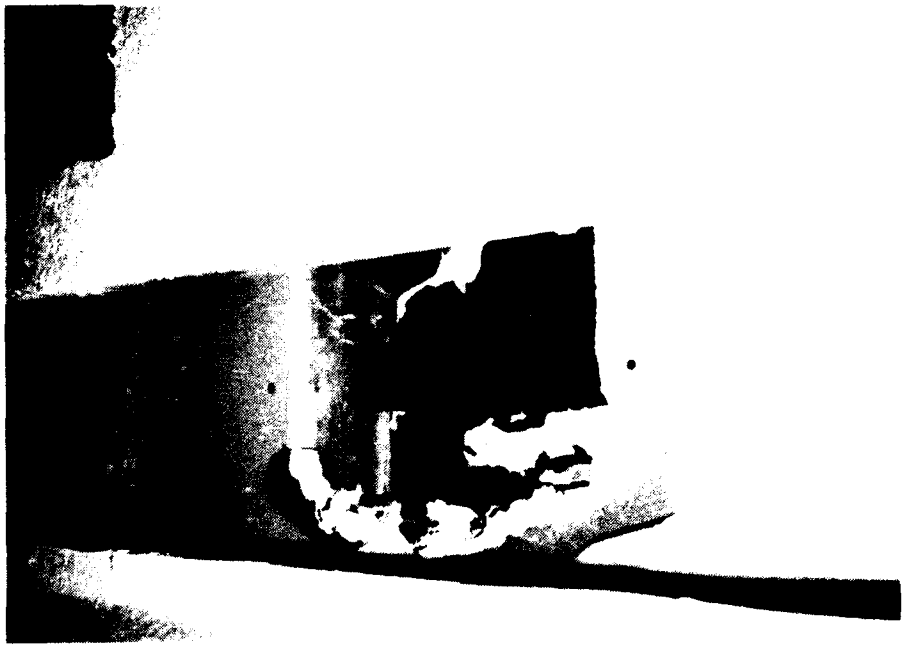


Figure F5: Plumbing over Hallway Air Plenum

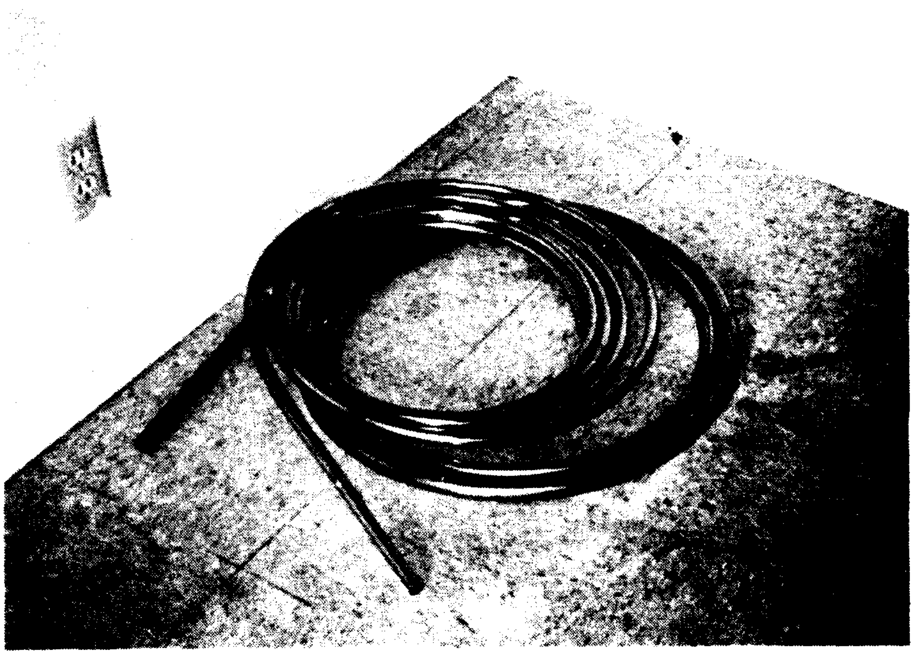


Figure F6: Flexible Copper Tubing

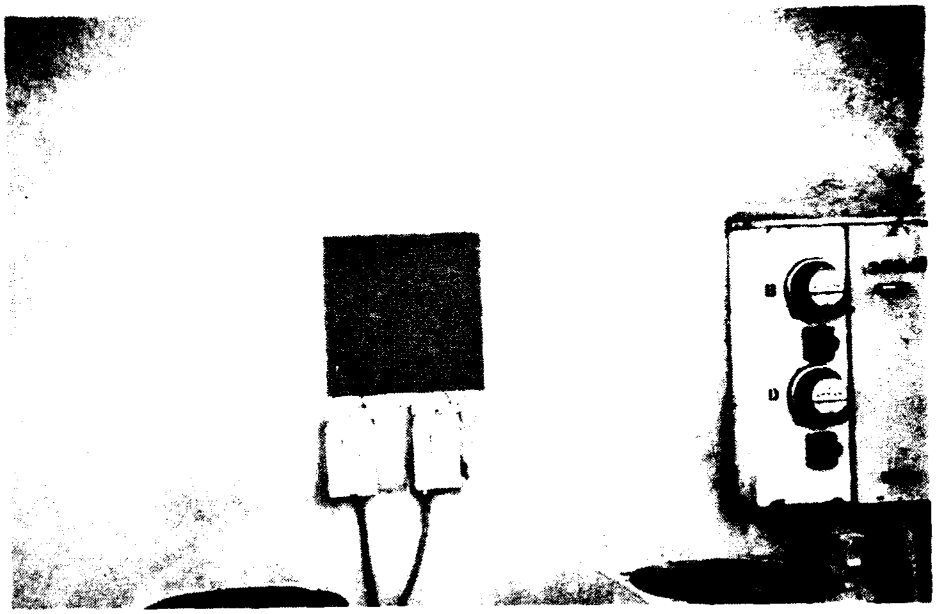


Figure F7: Exterior Wall with Electrical Service Junction Boxes

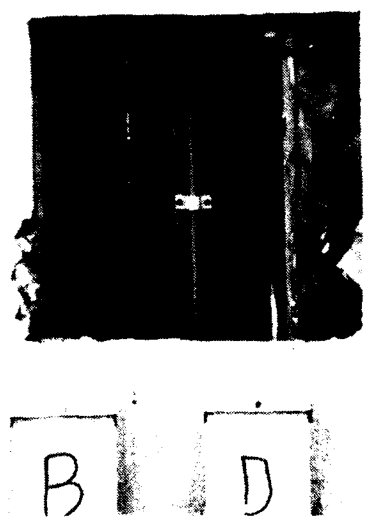


Figure F8: Non-replaced Polybutylene Pipe Section

4. INVESTIGATIONS:

Investigations performed by USACERL included observation of the plumbing replacement, interviews with Ft. Irwin DEH and Dyna Corp. (the Ft. Irwin M&R contractor) employees concerning their experiences with the plumbing systems in the pre-manufactured housing, and a tour of a pre-manufactured housing assembly facility in Southern California. In addition, both failed and non-failed pipe and fittings were examined in the laboratory by chemical resistance testing, infrared spectroscopy and x-ray diffraction spectroscopy.

Plumbing Replacement:

The plumbing replacement was observed by the USACERL investigator at four points during the process: when the old plumbing was exposed in the downstairs apartments and initial pipe removal begun, when pipe removal was complete and the replumbing was beginning, when the replumbing was about fifty percent completed, and after the completion of the task.

Several problems were noted in the old plumbing system in building 3804 during the piping removal phase. When the utility room plumbing was removed for Unit D (from the ceiling of Unit A) a broken tee was discovered at the hot water feed line just below the water heater, and an adapter between the hot water polybutylene pipe and the gate valve for the washing machine in Unit A was broken. In the closet plenum (Figure 9) of Unit B, both the drinking water supply riser and the regular water supply riser for Unit C were found to each have nails driven into them (Figure 10). Since they both carried cold water, the thermal contraction of the polybutylene around the nails was probably enough to keep them from leaking for the present time. Figure 11 is a microscopic view of one of the nail holes. It is evident that there is rust in the hole indicating that the nail was corroding. Had the corrosion progressed enough, it would have begun leaking. Finally, over the doorway between the kitchen and living room in Unit B, both the hot and cold water pipes were crushed by a nail driven through the metal plumber's strap (Figure 12) as depicted in Figure 13. The plumbing for Unit A that was in the crawl space under the unit was examined but no broken pipes, fittings or probable leaks were found. There were, however, several places where copper pipe and fittings had been used for leak repairs in the past Figure 14). The plumbing for Unit B within its crawl space was not examined.

In addition to observing the pipe replacement, water temperature and pressure measurements were conducted. Since the water was disconnected in building 3804, the water temperatures in nearby housing units were measured. Water temperatures were measured by fastening an iron/constantan thermocouple to the kitchen water faucets (Figure 15), allowing the water to run until the temperature remained constant and recording the temperatures detected. Table 1 is the result of the measurements. The second two sets of temperatures were measured 10 days after the first ones, this time by using a mercury thermometer (Figure 16). The tenant in Unit 3807A was advised to turn down the thermostat on the water heater (during the first visit) for safety of his small children. The water pressure was measured

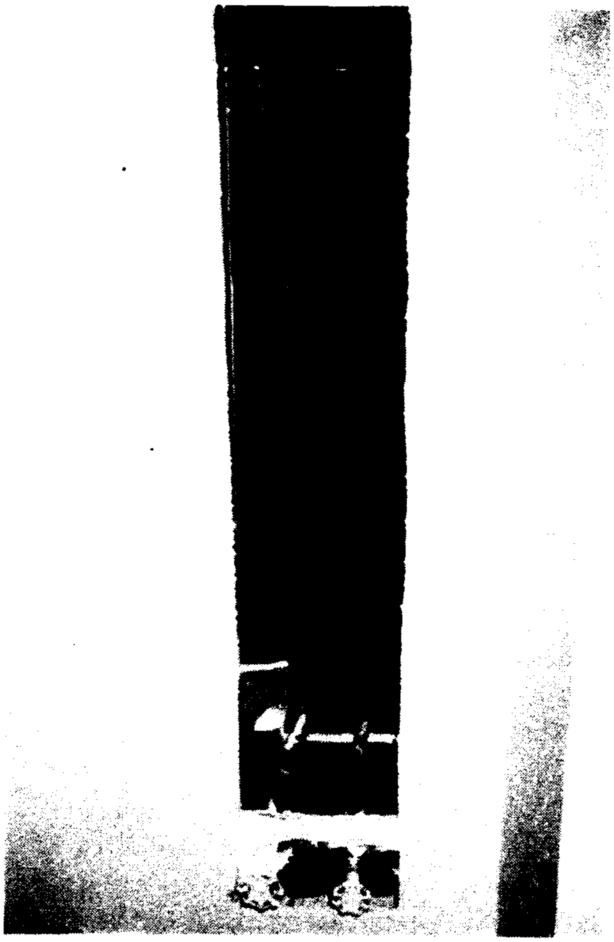


Figure F9: Polybutylene Pipe in the Closet Plenum

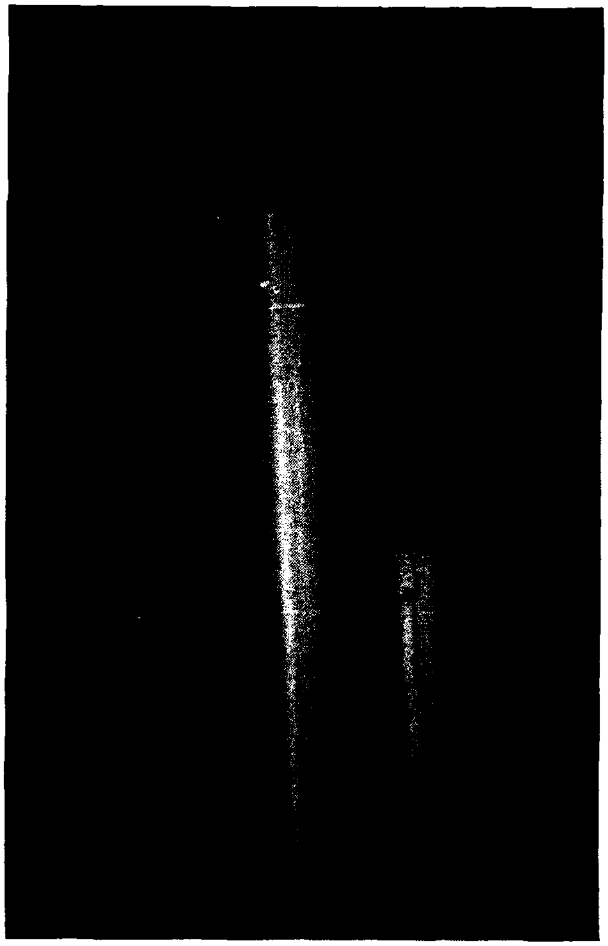


Figure F10: Nail Holes in Pipe Removed from Unit B

Figure F11: Microscopic View of Nail Hole

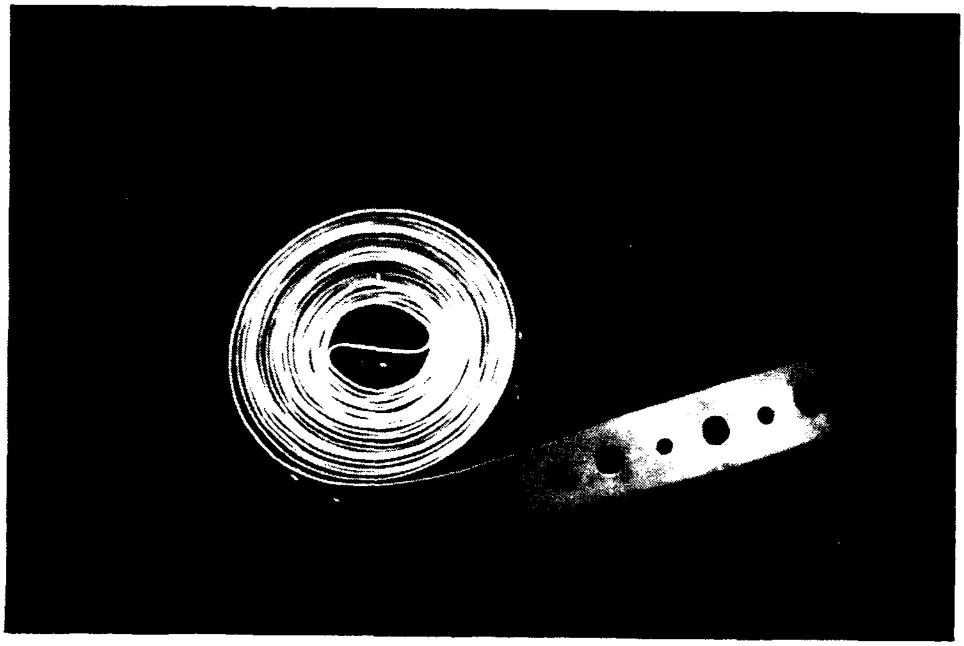


Figure F12: Plumbers Strap

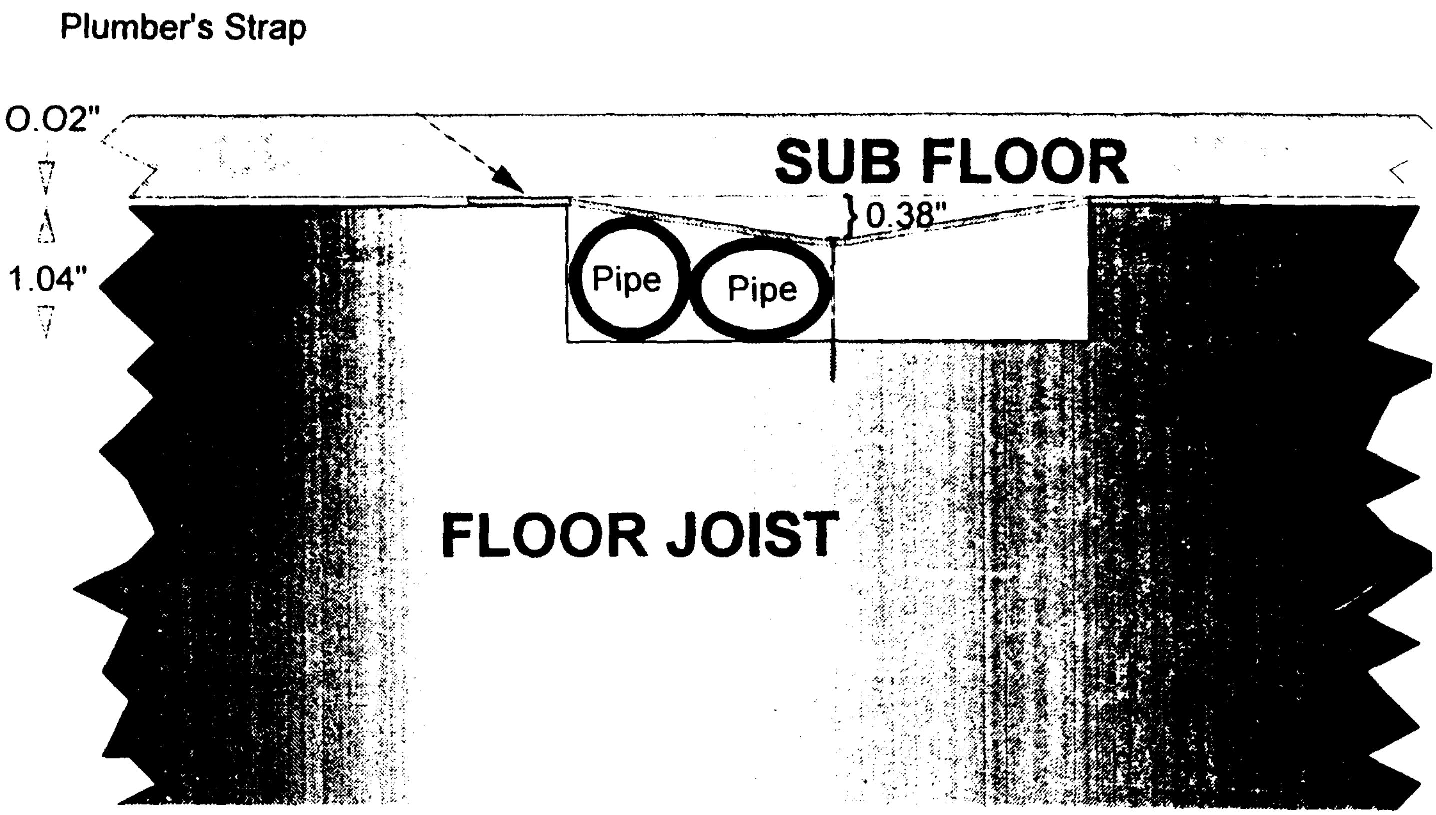


Figure F13: Drawing of Crushed Pipe Site

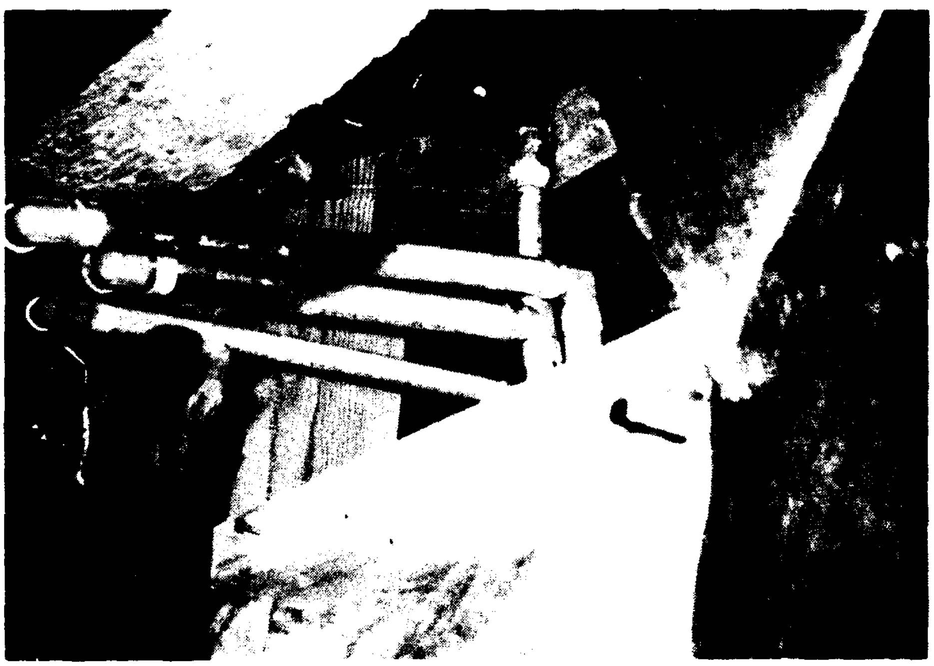


Figure F14: Previous Leak Repairs in Crawl Space under Unit A

Figure F15: Temperature Measurement Using Iron/Constantan Thermocouple

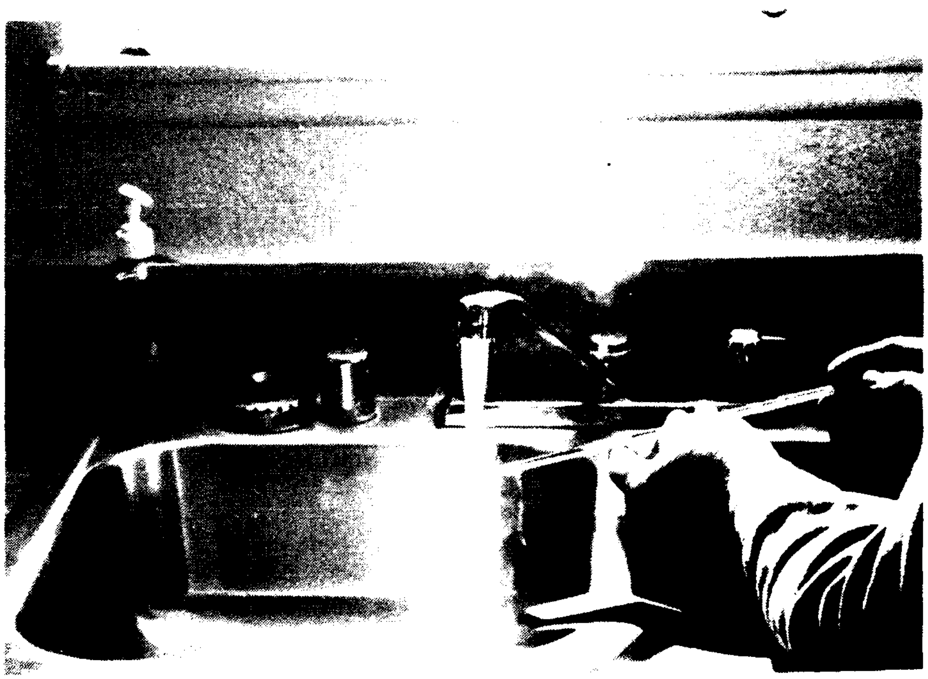


Figure F16: Temperature Measurement Using Thermometer

using a standard pressure gage which was attached to external water bibs. Two pressure readings were taken; both readings were 39 pounds per square inch gage pressure.

The contractor was observed assembling replacement plumbing system. He was very conscientious in his assembly technique and took care to do the work right. The plumbing installed for units 3084B and 3804D was inspected and appeared to be top quality work complying with Army and industry practice.

Interviews:

Mr. Walt Perry, the Ft. Irwin DPW Chief of Maintenance and OperationsBranch, Mr. Bob Caddell of the Ft. Irwin DPW, Mr. Smokey McCulley, the plumbing supervisor for Dyna Corp., and Mr. Don Andrews, a plumber employed by Dyna Corp. were interviewed concerning their experiences with the piping failures in the manufactured/factory-built housing units. They all stated the same basic views:

(1) 95 percent or more of the plumbing leaks and breaks have been in the acetal pipe fittings, while 5 percent or a little less have been in the polybutylene pipes themselves.

(2) The failures began in the hot water lines and after a period of around six months began to occur in the cold water lines.

(3) Initially, all of the failures were in the fittings. However, over the last couple of years they have been experiencing more and more failures in the polybutylene pipes, primarily in the hot water pipes.

(4) When repairs are made, copper tubing and fittings are used instead of plastic.

(5) Approximately 75 percent of the failures have occurred under the houses.

(6) Most of the leaks, maybe 90 percent, have occurred at the water heater (Figure 17) or in the wall or right under the floor adjacent to it.

(7) The plastic ball valves and gate valves foul or seize up and get twisted off, with the faucet connectors and pipe joints breaking most frequently.

A plumber who had been called to building 3808 because of a plumbing leak was interviewed. He stated that they had had twelve calls so far that day due to plumbing leaks in the Ft. Irwin pre-manufactured housing area.

Tour Observations:

The Western Homes Corporation assembly plant in Corona, CA was visited in order to observe the current pre-manufactured housing construction practices. According to Erv Ginkel, a sales representative for Western Homes Corp. they had submitted a bid for construction of the pre-manufactured housing units at Ft. Irwin.

In the housing that was being assembled at the time, they were using polybutylene plumbing as had been used in those at Ft. Irwin. The differences between what was installed

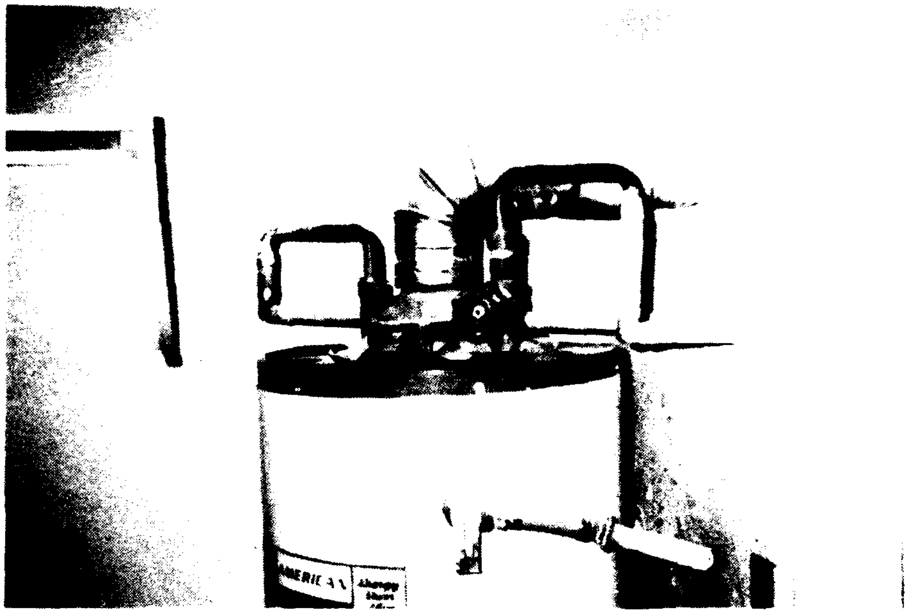


Figure F17: Pluming Repairs at Hot Water Heater in Building 3804, Unit A

at Ft. Irwin and what they were installing was that they were fastening the pipe to the floor joists using semi-circular pipe hangers, and they using copper fittings exclusively rather than acetal.

Laboratory Testing:

Laboratory testing consisted of visual examination, optical microscope examination, chemical resistance testing, infrared spectroscopy and x-ray diffraction spectroscopy.

Samples of failed pipe and pipe fittings from Ft. Irwin were visually examined. Nearly all of the acetal fittings had a white coating on the inside. Selected failed samples were cut in half longitudinally using a band saw to expose the inside for examination. Breaks and fracture surfaces were then examined more closely using an optical microscope.

A long term exposure test of the acetal fittings was conducted to evaluate the characteristics of the pipe fittings when exposed to the two types of potable water used at Ft. Irwin and a high concentration of hypochlorite in solution. Non-discolored (i.e. no white coating on the inside as depicted in Figure 18) acetal pipe fittings removed from the vent pipes from hot water heaters in building 3084 were placed in three glass jars. Also included in the jars were new acetal fitting parts purchased by USACERL. Ft. Irwin drinking water was placed in one jar, Ft. Irwin regular potable water was placed in another of the jars, and

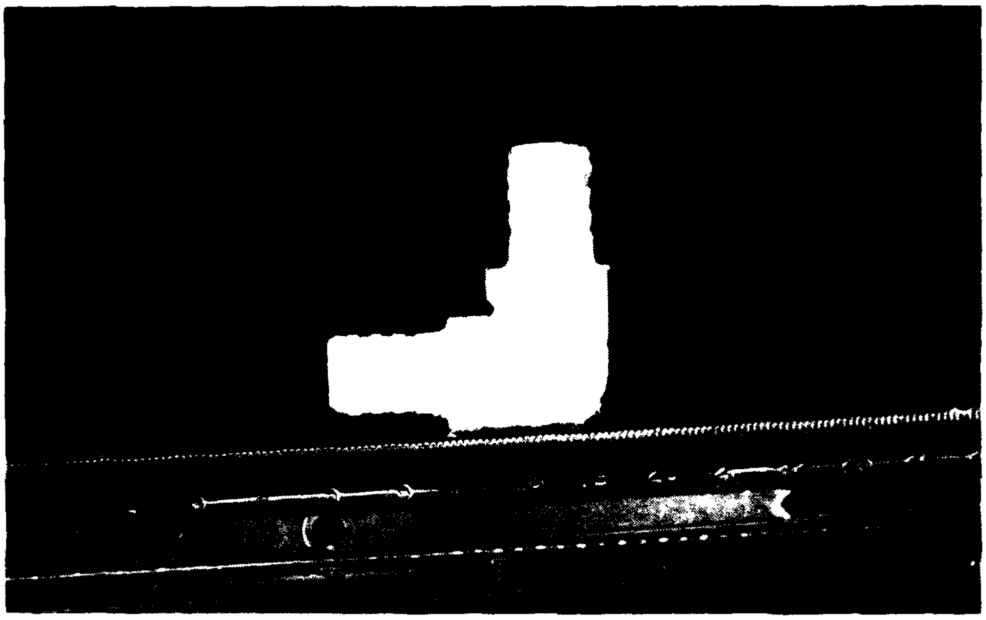


Figure F18: Typical Cross-Section of Acetal Fitting from Ft. Irwin Plumbing

Chlorox bleach, a 5.25% solution of sodium hypochlorite, was placed in the third. The three jars were placed in an oven for five months at a temperature of 70 Centigrade.

Potassium bromide pellets were prepared containing 1% (wt.) filings from the grey exterior of an acetal fitting from Ft. Irwin and another containing 1% (wt.) filings from the white interior of the same fitting. Similar pellets were prepared using residue of deteriorated acetal from the long term exposure testing. These pellets were examined using Infra-red (IR) Spectroscopy.

Finally, samples of the acetal fittings were were examined using x-ray diffraction. Both the grey outside of the fittings and the white colored inside, as well as filings left over from the IR test, were examined.

Laboratory Test Results

The visual examinations of the polybutylene pipe failures revealed that at the locations where leaks occured, the pipe cross-section was oval shaped instead of round. Four sections of failed polybutylene pipe were secured for investigation as to the cause of the failures: two were provided by Mr. Walt Perry and two by Mr. Don Andrews. One pipe provided by Mr. Perry (Figure 19) was ruptured, having a hole 1.56 inches long (in the longitudinal direction) and 0.44 inches wide. There were two long narrow strips of pipe wall material broken free

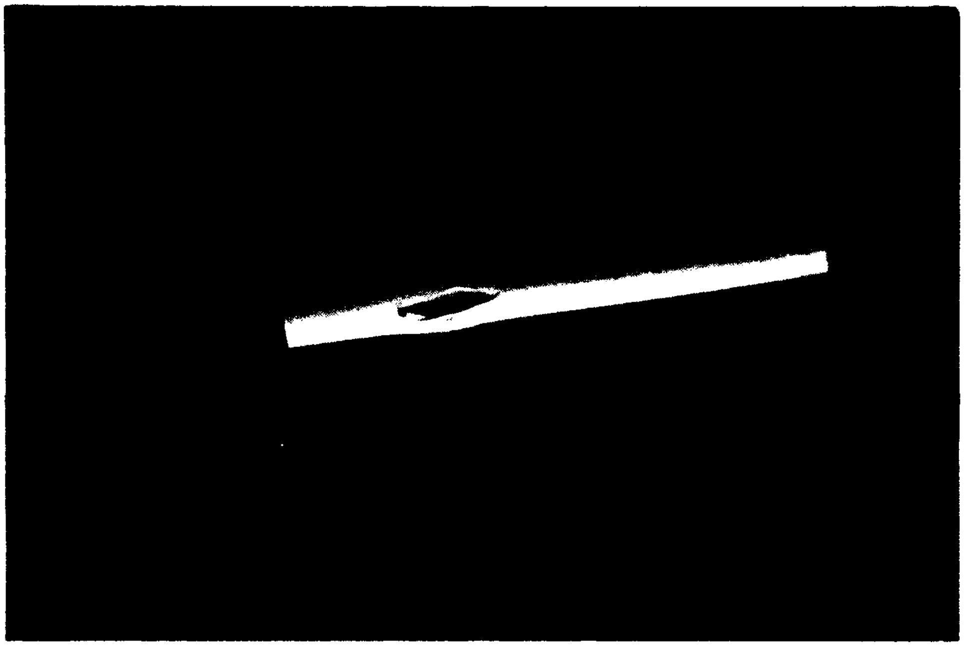


Figure F19: Ruptured Polybutylene Pipe from Building 3858, Unit C

from one end of the rupture The other three pipe failures had longitudinal hair line cracks in them (Figures 20 and 21)

Visual examination of the failed fittings removed from the plumbing at Ft Irwin showed three things in common, (1) they all had a white coating where they were exposed to the water (Figures 22 and 23), (2) all but one (96.5%) of the breaks were at the compression fitting, and (3) the fracture surfaces had the white colored surface on them except for what appears to be a final fracture break area (Figures 24 and 25) The one fitting that was the exception to being broken at a compression fitting, broke diagonally across the entire fitting It was not clear if the crack initiated at a compression fitting point or not

At the completion of the long term chemical resistance testing, there was evidence of chemical attack of the acetal fittings in all three environments One evidence was the presence of a fine grey powder suspended in the bottom of the jars The powder was filtered, dried and weighed The dried powder became the same white color as the inside coating of the fittings The drinking water sample contained 0.023 grams of powder, the potable water had 0.097 grams, and the Chlorox filled jar had 0.223 grams of suspended particulate The fine powder was evaluated by IR Spectroscopy Figure 26 is the spectrograph of the drinking water test residue and Figure 27 of that from the hypochlorite solution test (The residue from the potable water test was accidently thrown into a trash container and lost before KBr pellets were made) The other indicator of chemical attack was the visible start of discoloration on

Figure F20: Longitudinal Hair Line Crack in PB Pipe from Building 3802, Unit B

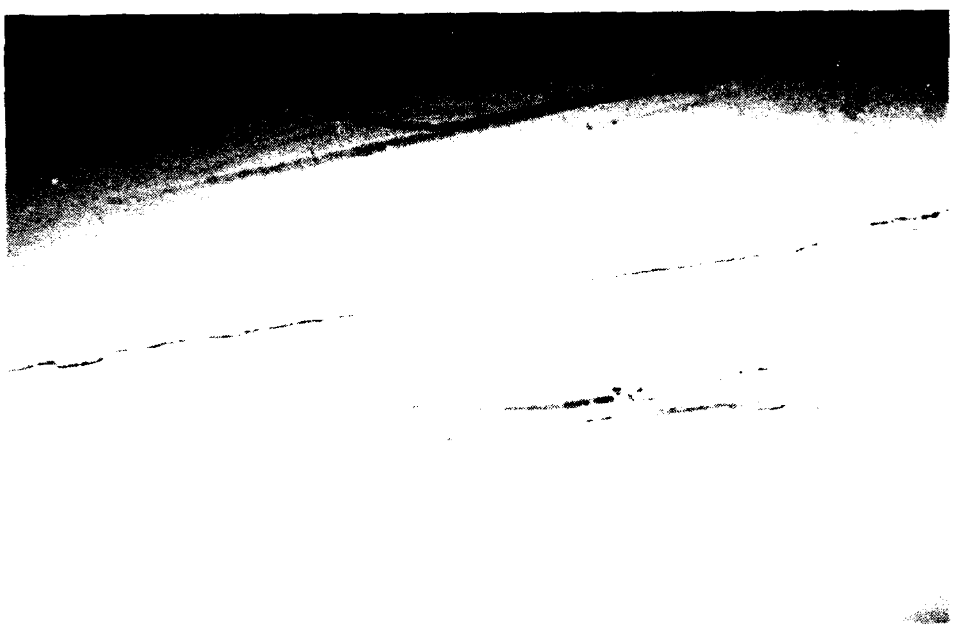


Figure F21: Microscopic View of Longitudinal Hair Line Crack

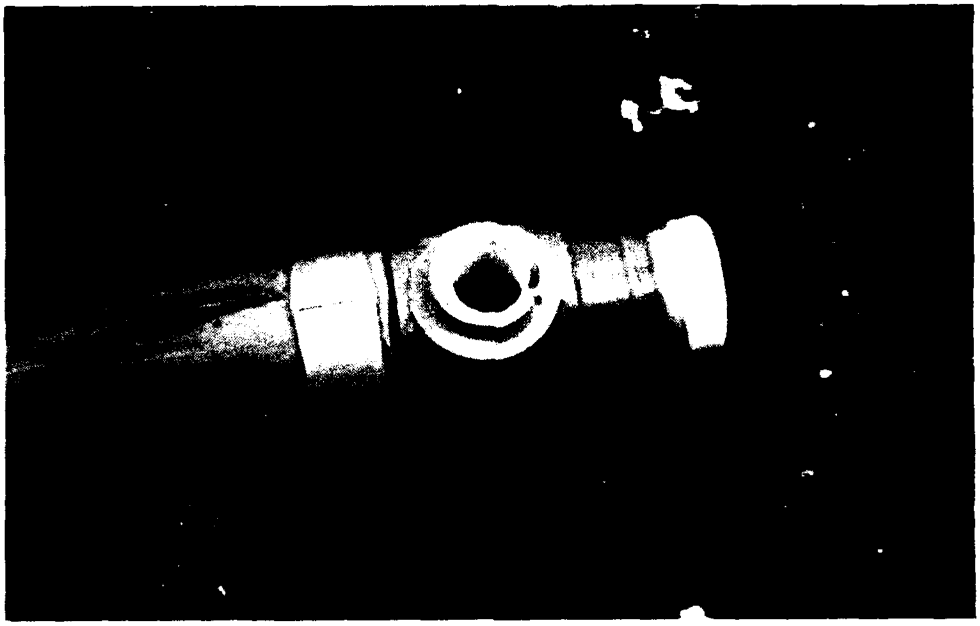


Figure F22: White Coating on Acetal Fitting Where Exposed to Water

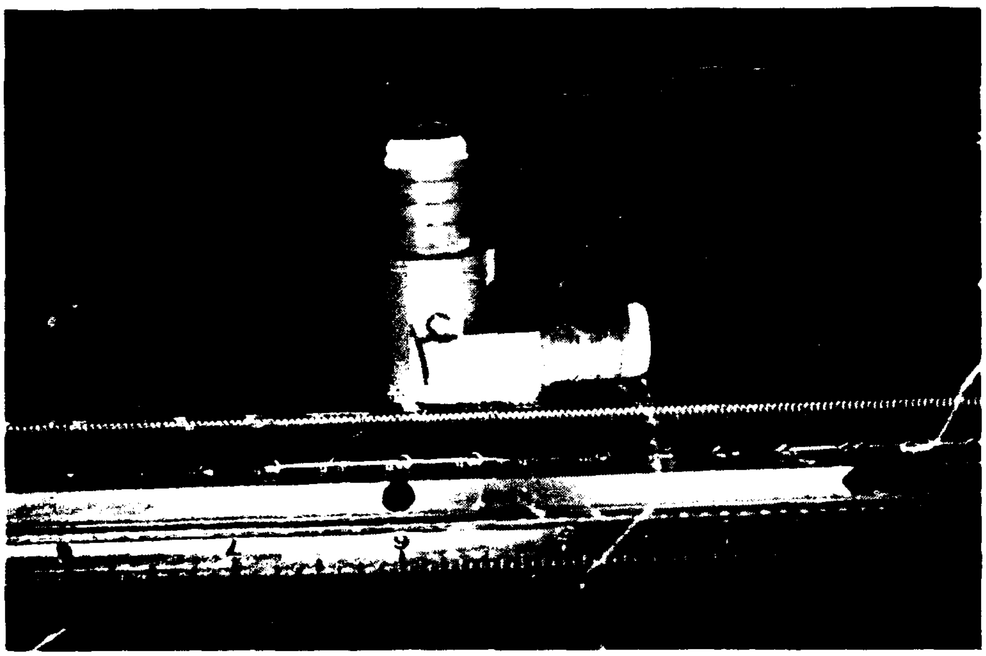


Figure F23: White Coating on Acetal Fitting Where Exposed to Water

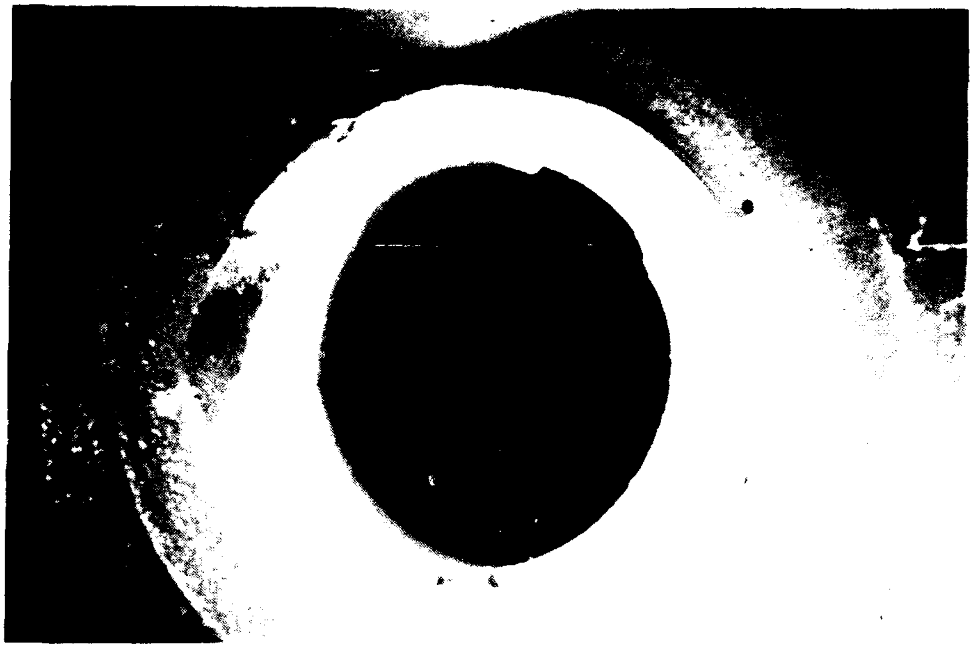


Figure F24: Typical Ft. Irwin Acetal Fitting Fracture Surface

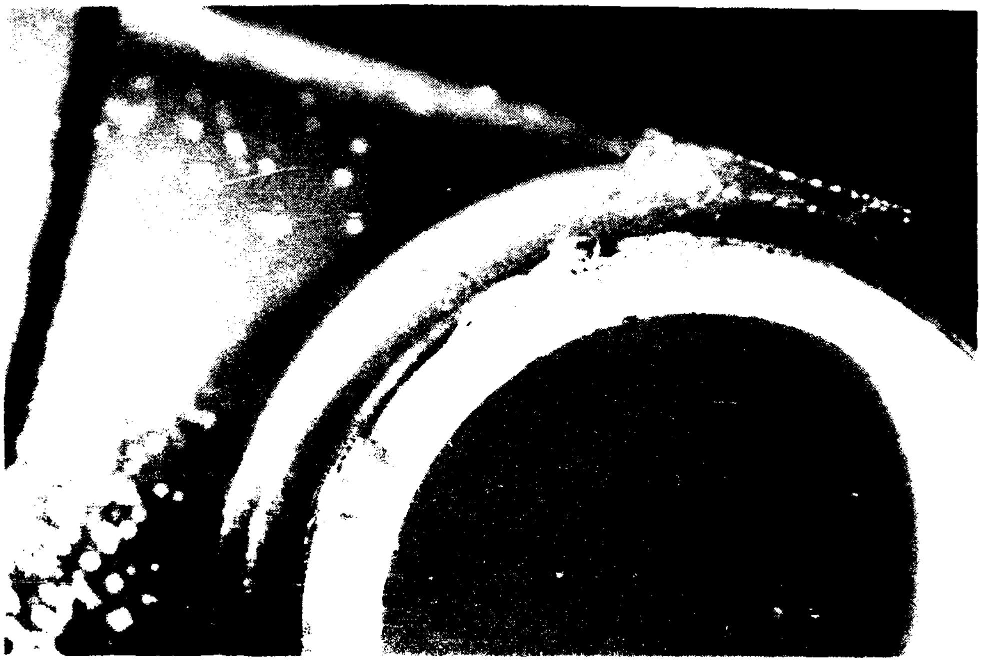
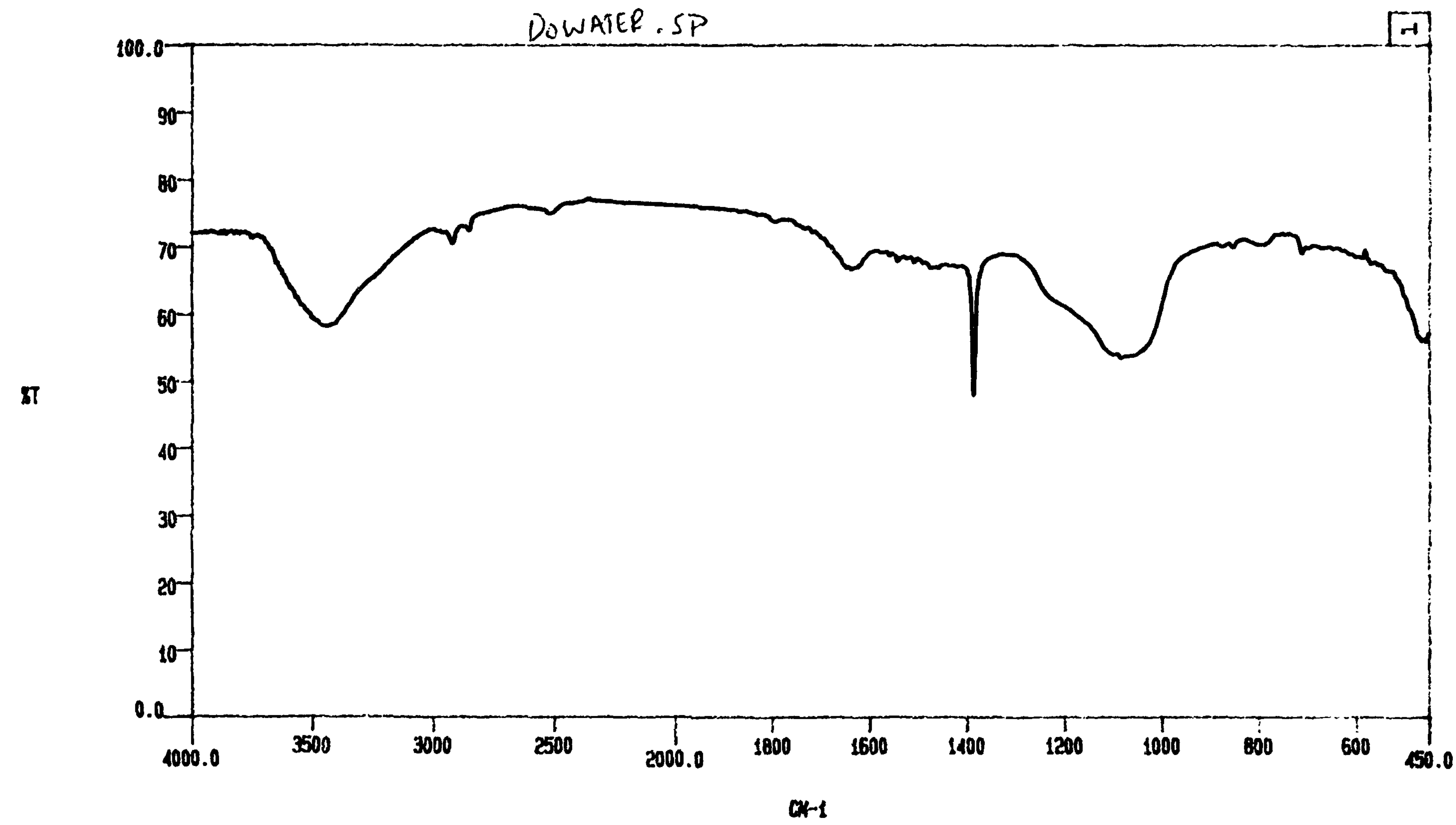
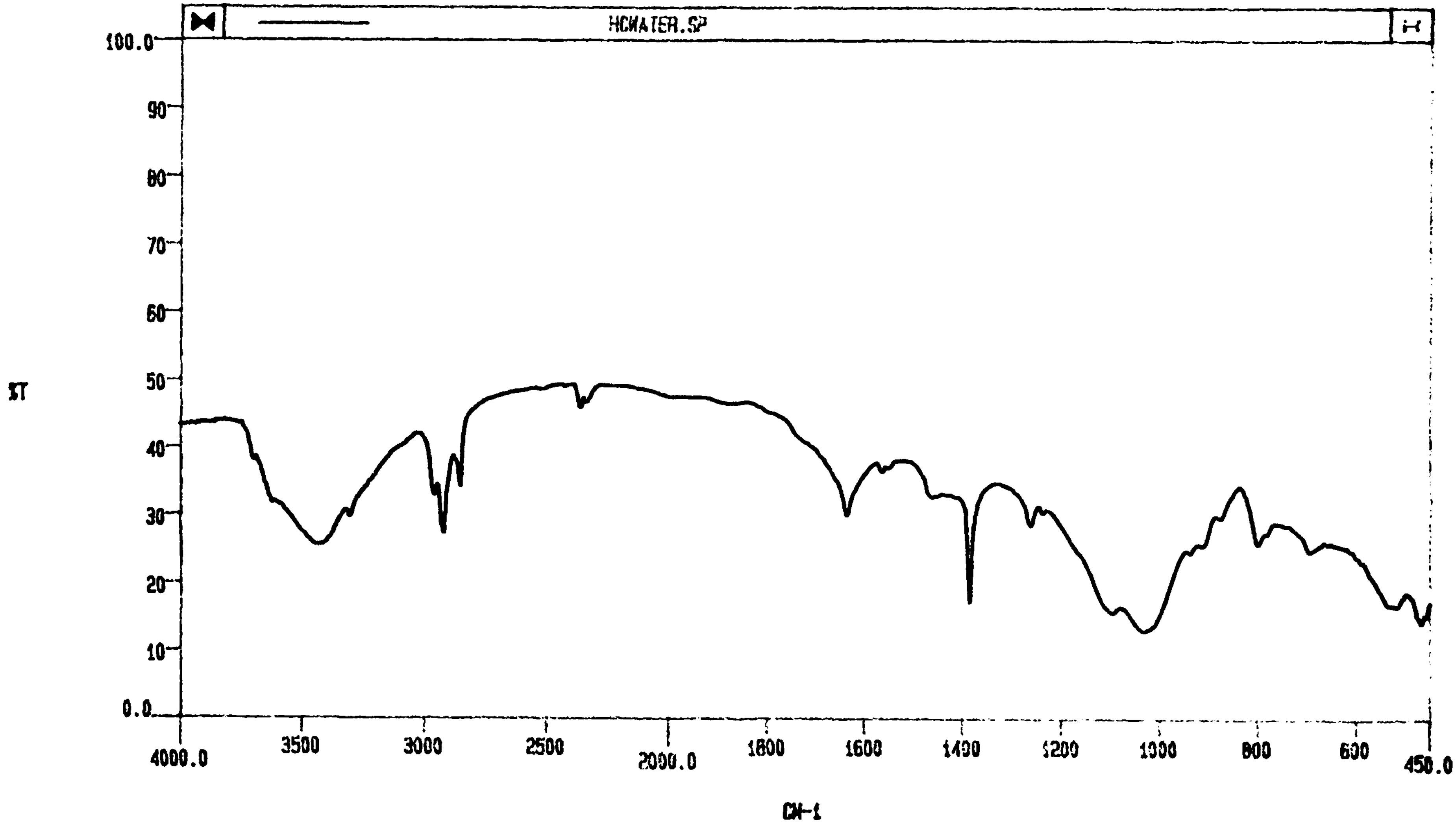


Figure F25: Typical Ft. Irwin Acetal Fitting Fracture Surface



P-E 1700 Filename: Date: 92/09/23 Time:
Scans: 5 Resolution: 4.00 Operator:
Sample:

Figure F26: IR Spectograph of Residue from the Drinking Water Test



P-E 1700 Filename: HCWATER.SP Date: 92/09/24 Time: 12:07:01.00
Scans: 5 Resolution: 4.00 Operator:
Sample:

Figure F27: IR Spectograph of Residue from Hypoclorite Solution Test

the acetal specimens, especially in the high concentration of sodium hypochlorite. Figures 28-30 show the acetal samples tested in Ft. Irwin drinking water, potable water, and Chlorox.

The IR Spectroscopy scans revealed that the white interior coating of the fittings is acetal that has been chemically modified. Figures 31 and 32 are the scans produced for the grey outer part and the white inner part respectively. Figure 33, showing the two scans overlayed, shows that all of the chemical components in the grey outer material are present in the white inner material. However, the white differs by two additional components, one at 2332 cm^{-1} and 583 cm^{-1} The peaks at 2332 cm^{-1} and 2030 cm^{-1} indicate the presence of some inorganic materials in the polymers.

In order to identify what the inorganics are, X-ray Diffraction Spectroscopy was used. The X-ray Diffraction indicated that titanium was present in the polymer material. Since titanium dioxide is commonly used as a colorant and natural acetal is white in color, the titanium dioxide is probably the coloring component used in the fittings. The colorant would correspond to the IR peak at 2030 cm^{-1}. The peak at 2332 cm^{-1} is a sulfite or sulfate formed from reaction with the high sulfate content water.

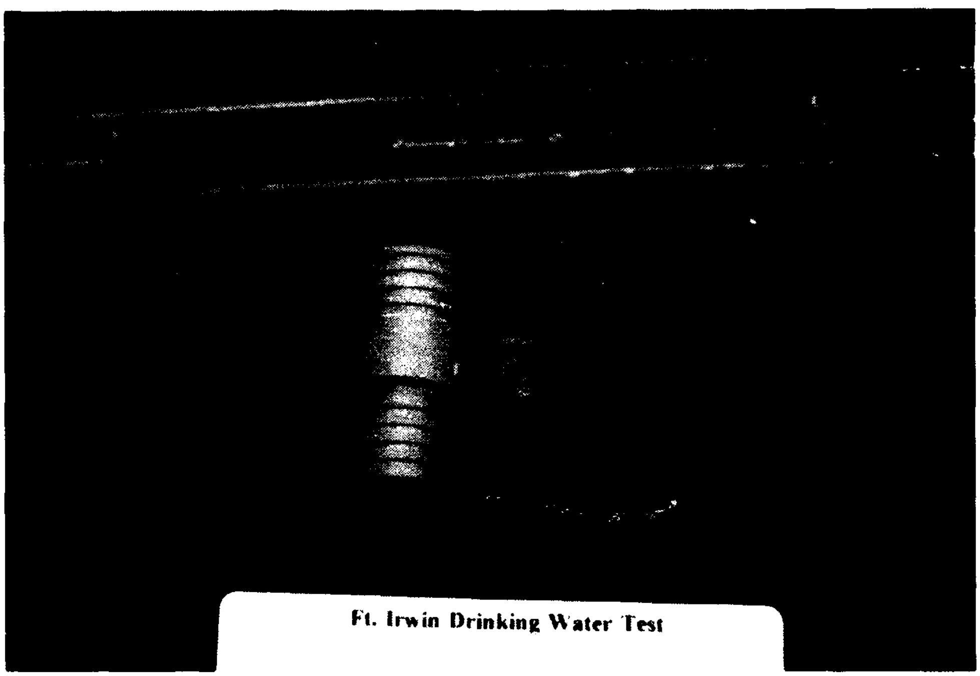


Figure F28: Acetal Fittings Exposed to Ft. Irwin Drinking Water

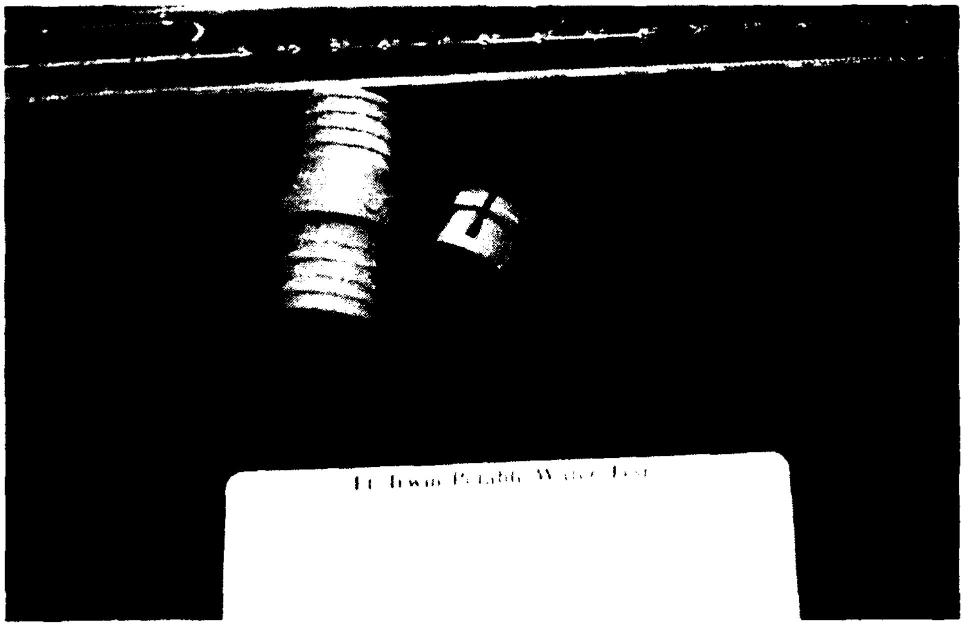


Figure F29: Acetal Fittings Exposed to Other Ft. Irwin Potable Water

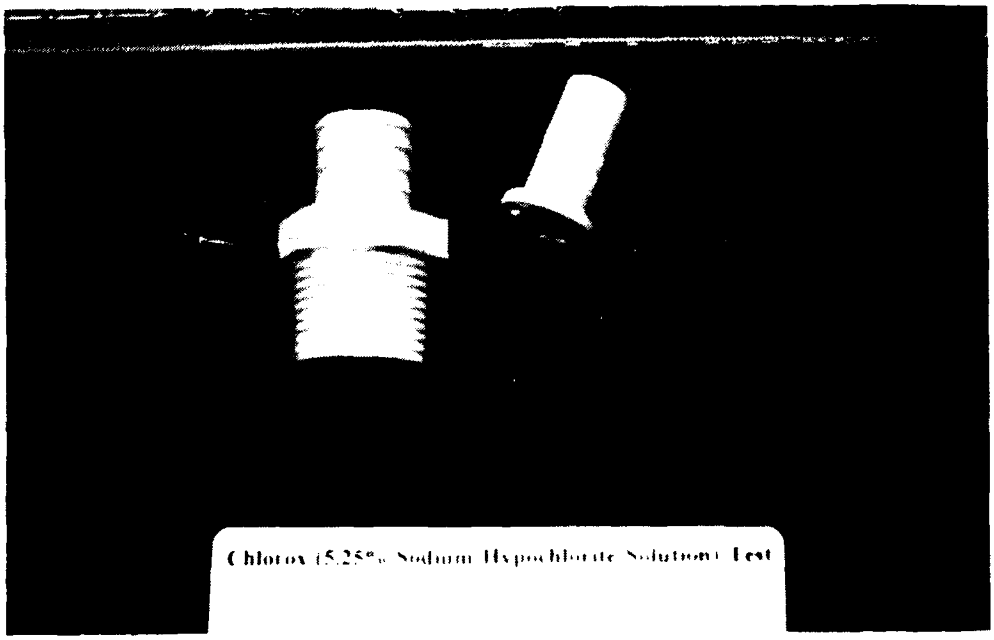
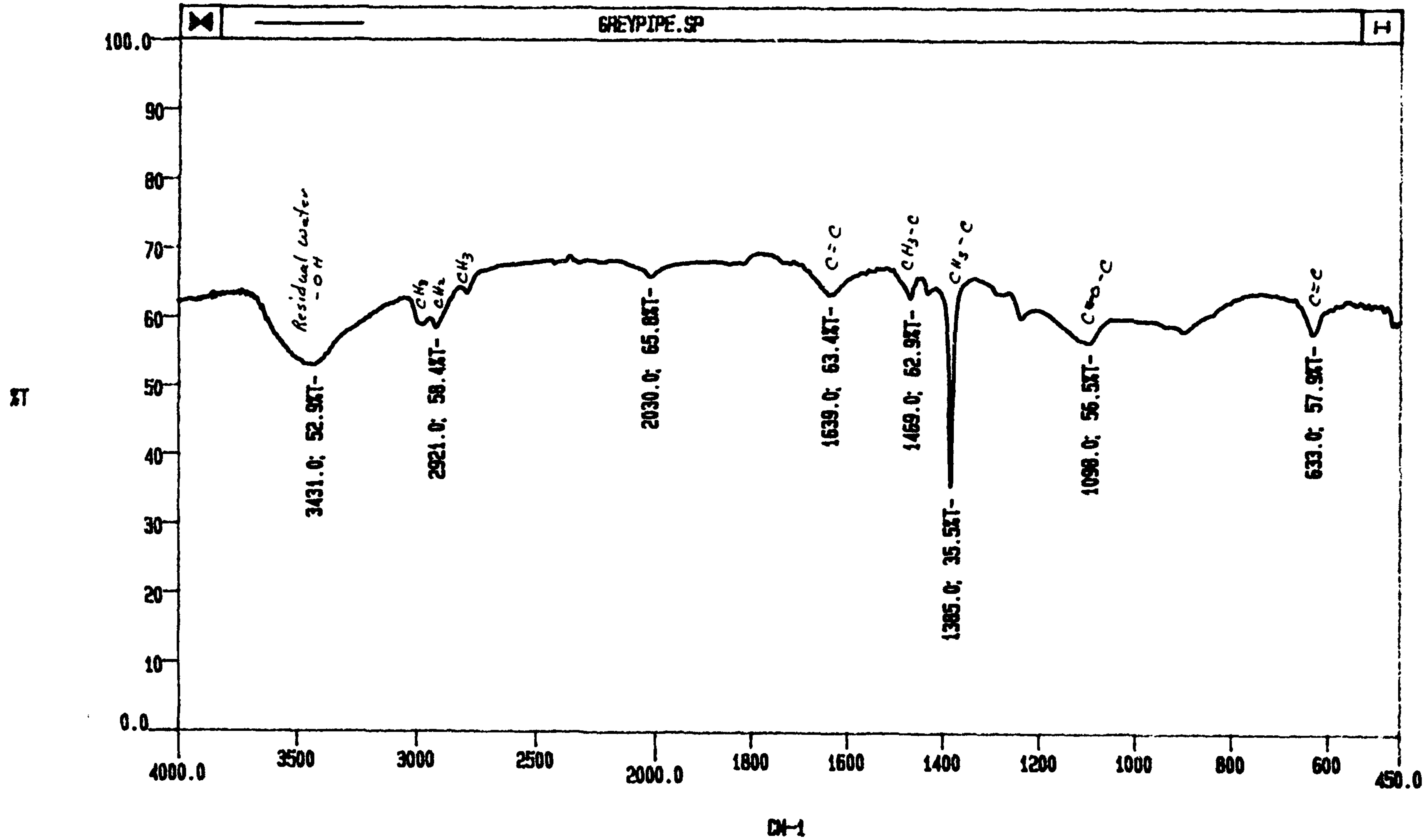
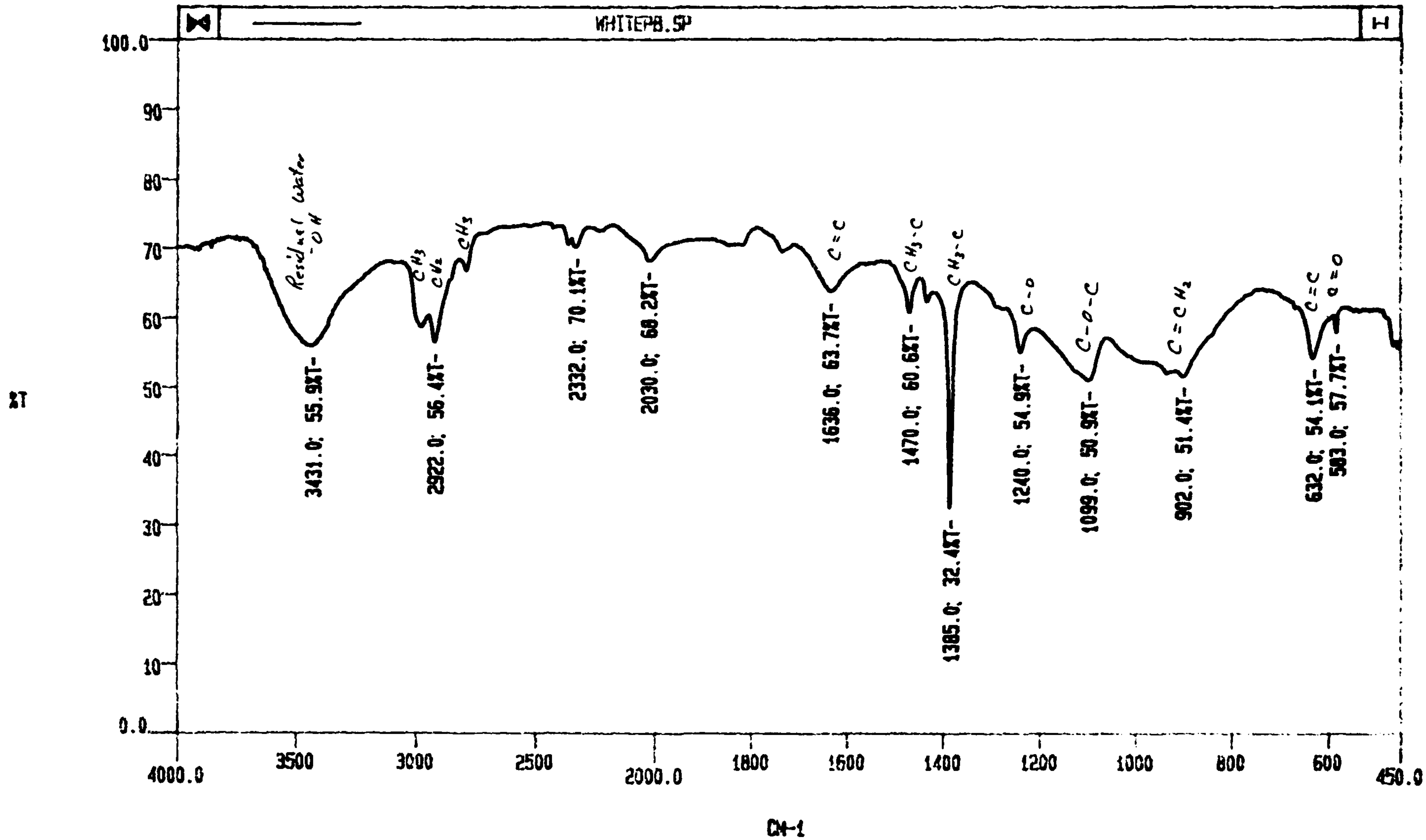


Figure F30: Acetal Fitting Exposed to 5.25% Sodium Hypochlorite Solution



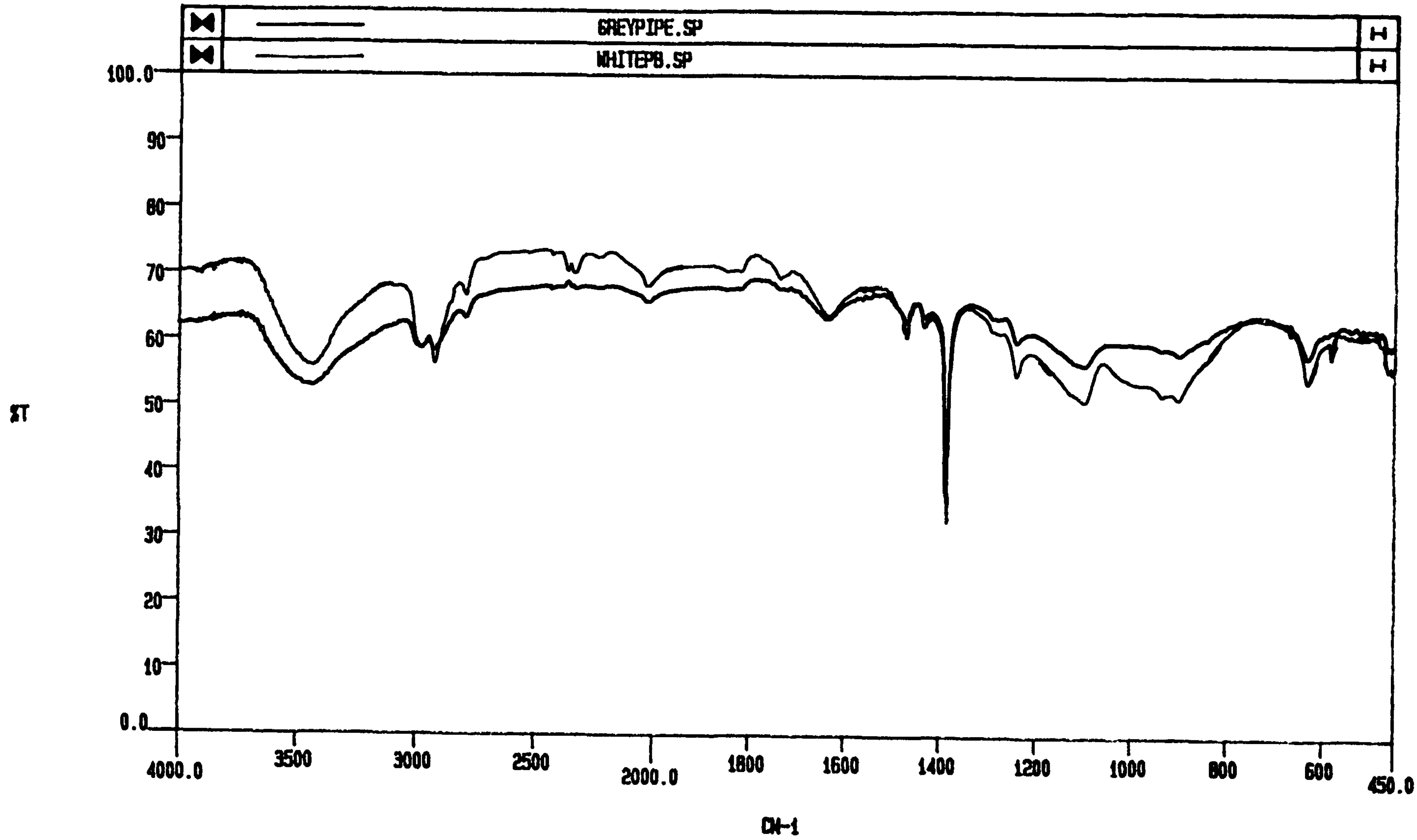
P-E 1700 Filename: GREYPIPE.SP Date: 92/08/28 Time: 11:07:56.00
Scans: 5 Resolution: 4.00 Operator:
Sample:

Figure F31. IR Spectograph of the Grey Exterior of a Typical Ft. Irwin Acetal Fitting



Scans: 5 Resolution: 4.00 Operator:
Sample:
Date: 92/08/28 Time: 10:31:53.00

Figure F32: IR Spectograph of the White Interior of a Typical Ft. Irwin Acetal Fitting



P-E 1700 Filename: Date: 92/08/28 Time:
Scans: 5 Resolution: 4.00 Operator:
Sample:

Figure F33. Overlay of Exterior and Interior Spectographs of Fittings

5. DISCUSSION:

The piping system installed in the manufactured/factory-built family housing units at Ft. Irwin is comprised of ½" and ¾" polybutylene pipe with Celcon[3] fittings. Celcon is the trade name of an acetal resin supplied by Celanese. It is the same materials and manufacturers as those reported by the CBS News program "60 Minutes" on 30 December 1990. The news program failed to stress that 95 percent of the leaks were in the Celcon fittings, and scenes depicting removal of pipes showed polyethylene pipe removal rather than polybutylene pipe according to the Society of Plastics Engineers.

Polybutylene Pipe:

Polybutylene, as does most polymeric materials, has a relatively high coefficient of thermal expansion. The coefficient varies between 128×10^{-6} to 150×10^{-6} inches per inch per degree centigrade. Based on the temperatures measured in the housing area, the coefficient of thermal expansion translates in a linear expansion of the hot water lines of between 0.41 and 0.76 inches for every 10 foot length of pipe.

A contributing factor for the broken tee found in building 3804 may have been the fact that there was room for only 0.875 inches allowed for linear expansion for the 21.25 foot length of pipe between the tee from the hot water heater supply line and tee to the kitchen sink. If the hot water temperature reached 125° F for any length of time, linear expansion of the pipe would force the tees at each end against immovable floor joists and the thermal cyclic loading would eventually break the fittings.

Polybutylene pipe is extruded when it is manufactured. Polybutylene is comprised of long chain molecules. The overall tensile strength of the polymer comes primarily from intermolecular chain entanglements and not from intermolecular attractions. During the extrusion process, most of the chains become oriented lengthwise in the direction of the extruding (more or less parallel to each other) and, as a result, more entanglements occur in the length direction than the hoop direction. Because of this molecular orientation, the pipe's hoop strength is much less than its length-wise strength . As long as the pipe stays near round, minimizing intermolecular stresses in the hoop direction, this molecular orientation presents no problems. However, if the pipe becomes out-of-round for some reason, the resulting internal stresses in the hoop direction increase the likelihood of the pipe developing a split due to disentanglement and stress shearing of the molecules. The long term effect is a longitudinal crack in the pipe wall. Thermal cycling can speed up the process.

As stated earlier, the polybutylene pipe that were secured for investigation all had longitudinal breaks or hair line cracks and in each case, the failures occurred at locations where the pipe was out-of-round. The cause of the pipe failures seen at Ft. Irwin is due to crushing of the pipe.

Celcon Fittings:

Celcon is a polymer with acetal bonds ($-O-CH_2-O-$) comprising portions of its backbone. It is formed by polymerizing trioxane (the trimer of formaldehyde) with a small amount of cyclic ether containing an oxyethylene ($-CH_2-CH_2-O-$) group.[1] The polymer is made stable after polymerization by depolymerizing the unstable end groups to the oxyethylene unit ($CH_2=CH-O-$). Figure 34 is a generalized schematic of the chemistry.

Acetals have the highest degree of crystallinity among all thermoplastics and, as such, have exceptional resistance to solvents, as well as fatigue resistance, surface lubricity and finish, and predictable strength and toughness properties over a wide temperature range. Problems occur in molded parts, such as the pipe fittings at Ft. Irwin, if they fail to reach full crystallinity, which is generally the result of processing with insufficient mold heat. Insufficient crystallinity can lead to performance problems such as part brittleness and excessive wear.[2] In addition, for molded acetal parts, contact with strong acids (aqueous solutions of 4.0 pH or less), strong oxidizers (solutions greater than 1 ppm hypochlorite or permanganate), and acidic salts (zinc chloride and other Lewis acid substances) is not recommended and can deteriorate the polymer.[3]

According to Walt Perry, sodium hypochlorite is used in the drinking water as a disinfectant. The concentration is more than 1 ppm. The remainder of the potable water is disinfected by injecting chlorine gas into it at certain intervals throughout the potable water system.

Chlorine gas hydrolyzes completely to form hypochlorous acid or hydrogen hypochlorite when it is injected into water. Figure 35 shows the relationship between pH and the distribution of the free available residual chlorine in water between hypochlorous acid and hypochlorite ion[4]. As the hypochlorite ion is consumed through oxidation, the residual hypochlorous acid dissociates to maintain the balance until it is totally consumed. The pH of

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[1]Modern Plastics Encyclopedia, Mid October 1991 Issue, Volume 68, Number 11, McGraw-Hill, Inc., New York, NY, pg. 10.

[2]Engineered Materials Handbook, Volume 2, Engineering Plastics, ASM International, Metals Park, OH, pg. 100

[3]Modern Plastics Encyclopedia, Mid-October Issue, Volume 68, Number 11, McGraw Hill, Inc., New York, NY, pg. 10.
Celcon Acetal Copolymer Properties CE-1A, Hoechst Celanese, Chatham, NJ, ppg. 9, 21, 22
Engineered Materials Handbook, Volume 2, Engineering Plastics, ASM International, Metals Park, OH, pg. 101

[4]Water Supply and Pollution Control, Third Edition, by J.W.Clark, W. Viessman, Jr., and M.J. Hammer, Harper & Row, Publishers, New York, NY, ppg. 448, 449

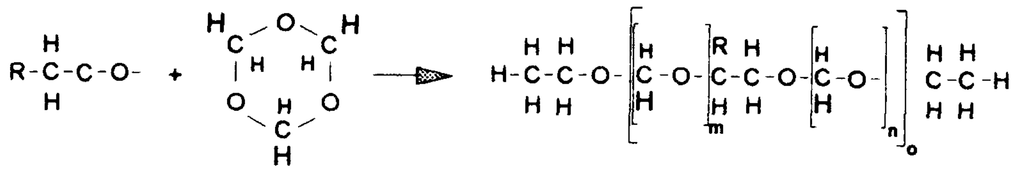

Figure F34: A Generalized Schematic of the Acetal Chemistry

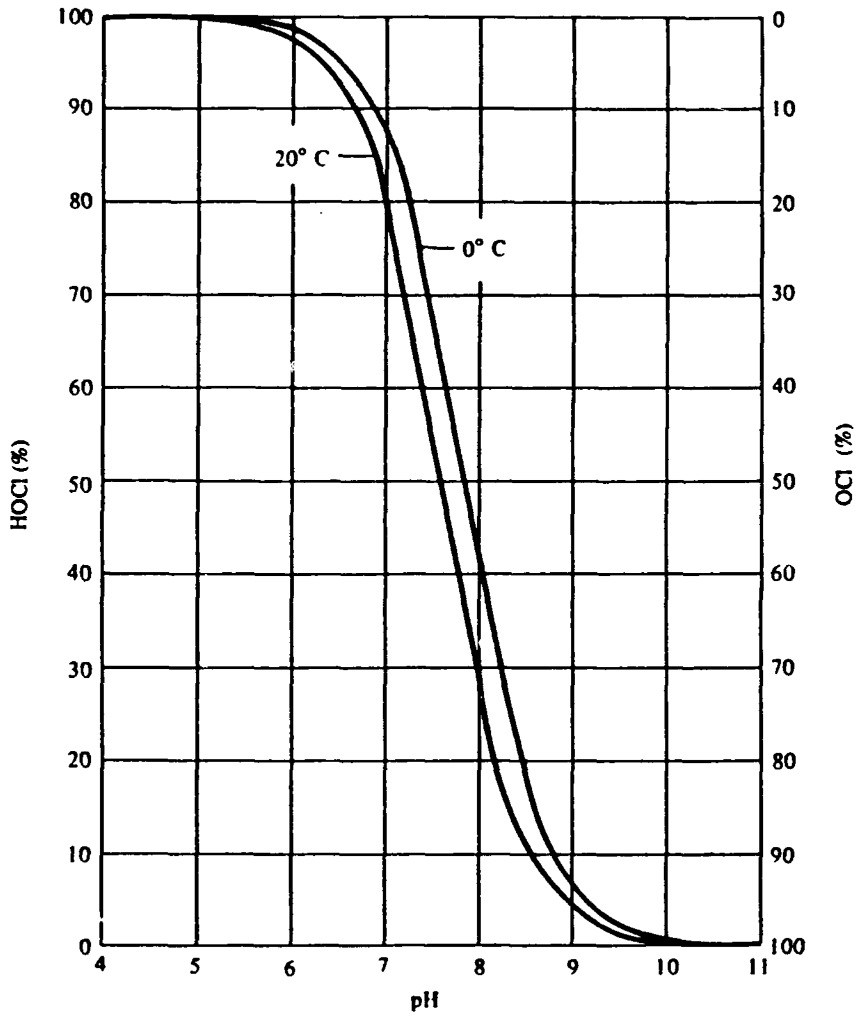

Figure F35: Relationship between HOC1, OC1-, and pH

the potable water from the outside bib of Housing Unit 3806B was measured at 7.61 and the drinking water obtained from the DEH office was 6.85 when measured at 20° C. Thus a strongly acidic pH was not evident.

The hypochlorite, being a strong oxidizer, can attack the acetal in two ways, it can strip hydrogen molecules off the polymer backbone and once the hydrogens are stripped off, hydrochloric acid (HCl) is formed which attacks the carbon-oxygen backbone causing it to breaking apart. The IR peak at 583 cm^{-1} indicates the presence of carbonyl (C=O) groups a product of HCl attack. For carbonyl groups to form, hydrogens must be stripped off of the polymer backbone and a carbon-oxygen bond broken. This process is what is refered to in literature as unzipping. Internal stresses in the polymer due to crimping the pipe to the fitting can enhance the rate of the chemical degradation and cause it to become more localized.

The discoloration pattern on the fracture surfaces of the fittings was very similar to stress cracking patterns observed in metals. There were smooth radial lines for the stress induced portion of the break and rough jagged edges where the part failed due to brittle fracture. All of the fitting failure surfaces examined had this pattern. From the inside they were white until very outside edge where the color is grey, indicating where the final brittle failure occured. Figure 36 shows the white discoloration penetrating into a crack that was forming.

The major reason for the pipe fittings to fail at Ft. Irwin was, therefore, a combination of the stresses induced by crimping coupled with the hypochlorite content of the water.

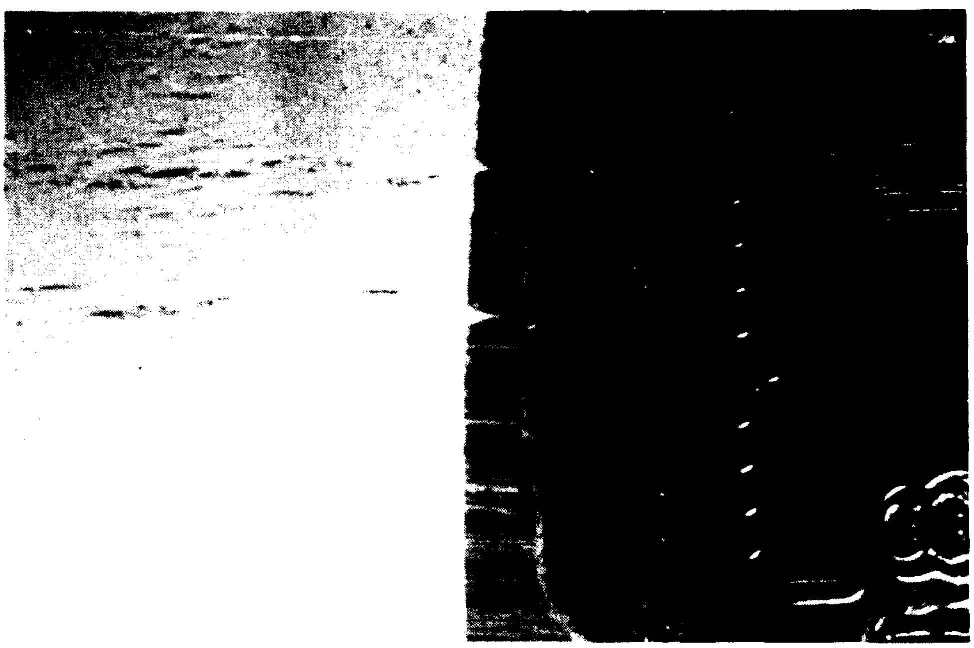

Figure F36: White Discoloration Penetrating into a Crack

6. CONCLUSIONS:

The conditions were right for chemical attack of the acetal to occur. Tests indicate that there were several underlying causes of the pipe failures. The failures experienced in the polybutylene pipes were due to pinching, flattening or crushing, and excessive confining of the pipe during construction. These problems would, for the most part, be difficult to foresee occuring. Without any history of failure to indicate possible problems, it would be hard to predict during construction that the pipes would fail in this manner.

The likelihood of the Celcon fittings failing should not have been hard to predict. However, in the contract submittals provided by the contractor (Appendix C) copper could have been used rather than Celcon fittings. The product specification literature for Celcon (Appendix D) states the dangers of using Celcon with water with high oxidizing agents. The contractor either failed to read it or ignored it since he could not use copper in the drinking water system because of that water chemistry. The sanitation procedure outlined in CEGS 15400 specify the use of 50 ppm hypochlorite cleaning for 24 hours and then leaving no less than 25 ppm in the system. Concentrations over 1 ppm will initiate chemical attack. The result has been that the Celcon fittings have failed due to a combination of stress induced by crimping the polybutylene pipe onto the fittings and the presence of the hypochlorite in the water.

The plumbing systems in place in the manufactured pre-built housing at Ft. Irwin is the result of very poor quality workmanship. CEGS 15400 paragraph 3.1.2.4 prohibits waterlines from bearing directly against building structural elements so as to prevent flexible movement of the lines. Plumbing in the wall adjacent to the hot water heaters in building 3804 did not allow sufficient space for thermal expansion nor the hot water run in Unit A to the kitchen sink. The same paragraph states that Bent pipe showing kinks, wrinkles, flattening or other malformations will not be acceptable.

Because to the choice of materials by the contractor who built and erected the housing units and the workmanship allowing the pipes to be crushed or flattened and nails to be driven into them, the plumbing system in the pre-manufactured housing area is failing and will continue to fail. This will cause great expense to the government. Due to the inaccessibility of the fittings for replacement, the presence of crushed and punctured pipes at seemingly random locations within the housing units, and the expense incurred by the government as a result of leaks and breaks, the entire piping system should be abandoned in-place and replaced with a new system. A combination of CPVC for the drinking water and copper for the remaining potable water system is the best solution.

7. RECOMMENDATIONS:

The plumbing system in the pre-manufactured housing area of Ft. Irwin should be replaced using a combination of CPVC for the drinking water and copper for the remaining potable water system.

CEGS 15400 should be modified in the following ways:

(1) A note should be added to paragraph 3.1.4.6 entitled "Plastic Pipe" which states that designers will not allow the use of acetal valves or fittings in distribution systems containing chlorine treated or chlorinated water. Copper, brass, or polybutylene valves and fittings should be used.
(2) A similar note should be added to Table II "PIPE AND FITTINGS FOR PRESSURE PIPING SYSTEMS".
(3) Paragraph 3.1.2.4 states that, "Bent pipe showing kinks, wrinkles, flattening, or other malformations will not be acceptable". A not should be added to See Additional Note C, and a statement added to note C stating that for extruded plastic pipe kinks, wrinkles, flattening or other malformations are a special concern to prevent premature pipe failure.

TABLE 1
Housing Water Temperatures

HOUSING UNIT NUMBER	AIR TEMP	AMBIENT WATER TEMP	COLD WATER TEMP	DRINKING WATER TEMP	HOT WATER TEMP
3807A	76.5° F		70.0° F	65.4° F	150.1° F
3805C	79.5° F		68.0° F	60.9° F	127.0° F
3805B	72.0° F		67.0° F	-----	137.0° F
3807A	75.2° F	75.2° F	70.3° F	59.5° F	137.3° F
3805C	68.0° F	73.4° F	70.7° F	61.3° F	122.5° F

APPENDIX A
Memorandum: Ft. Irwin Manufactured Housing Water Pipe Problem
Prepared August, 1991 by USACERL

DEPARTMENT OF THE ARMY
CONSTRUCTION ENGINEERING RESEARCH LABORATORY, CORPS OF ENGINEERS
P.O. BOX 4005
CHAMPAIGN, ILLINOIS 61824-4005

REPLY TO
ATTENTION OF

CECER-FS (70-1y)

08 AUG 1991

MEMORANDUM FOR Director, USA Engineering and Housing Support Center, ATTN: EHSC-HM-O/Mr. Alex Houtzager, Humphreys Engineer Center, Kingman Building, Fort Belvoir, VA 22060-5580

SUBJECT: Ft. Irwin Manufactured Housing Water Pipe Problem

1. Reference various telephone conversations between R. Neathammer and Mr. Louis Layton, CEMP-MA, Mr. Bernie Wasserman, EHSC-FU, Alex Houtzager, EHSC-HM-O, Mr. Phillip Brozek, CESPK-ED-T and Messr. Walter Perry and Rene Quinones, Ft. Irwin DEH. Also visits to Ft. Irwin by L. Layton and R. Neathammer.

2. Two actions have been initiated to assess the magnitude of the problem. One is a detailed review of all work order information in our data base involving leaks, floor repairs (sheet vinyl, vinyl tile and carpet) and drywall repairs (walls and ceilings). Table 1 summarizes these costs for the past seven years. It is not possible at this time to delete floor and wall/ceiling repairs which did not result from water leaks. Thus the data in this table show the upper limit for total costs. It is obvious that the number of leaks and their direct plumbing repair cost has dramatically increased in the past year. (We do not have all the June data yet so cannot see if this trend is continuing or accelerating). Note that the upper limit for total repair costs is $35K for the past year of occupancy. If this continues to increase, the cost of replacing all piping may well be warranted. If it has reached a steady state, then $35K expenditure for a few years may well be the solution, as eventually all or nearly all of the defects will be replaced. However, this does not consider the impact of all these repairs on occupants.

3. Table 2 shows costs for the last year for each of the buildings (four apartments in each). Ft. Irwin DEH should check this over in detail to see if we're missing any large costs. Also request that Ft. Irwin provide any information as to other costs to the government such as damages to occupants' furnishings that the government paid, damages to government owned furnishings, cost of pest control needed due to leaks, cost of moving personnel out/in during repairs, etc. These costs are needed to add to the direct repair costs to get the total cost to the government of this problem. (There are also indirect costs (non-quantifiable) such as morale and health that also need to be considered.) Note there is a slight discrepancy in the totals for the last year flooring costs which will be resolved later.

08 AUG 1991

Another aspect to the problem is vacant apartments (loss of use) during repairs. The following apartments are currently vacant due to water leaks:

3803-A vacated 3 Jul 91
3803-D vacated 31 Jul 91
3804-A vacated 11 Jul 91
3804-A vacated 25 Jul 91
3804-D vacated 19 Jul 91

Building 3803 is the test building that will have all the piping replaced.

4. The second action is to obtain the transcript of the 60 Minutes program to find out details of the piping failures in the private sector manufactured housing in the SouthWest. Supposedly the same manufacturer made the material at Ft. Irwin. We need to know the time the material investigated in 60 Minutes was made compared to the material at Ft. Irwin. Also, what kind of failures occurred.

5. Once Ft. Irwin has given us any additional cost data and the transcripts have been studied, we may want to have a meeting either at Ft. Irwin or in Washington to decide any further actions. Possibilities are:

a. Obtain all the piping that is going to be taken out of the sample building that Ft. Irwin is going to have replaced. Have it tested by a laboratory to try to determine if the failures are due to material, water pressure/hammer, installation, etc. Inspect all buildings for possible future problems.

b. Based on information from the 60 Minutes transcript, decide if actions with the piping manufacturer are possible.

c. Recommend Ft. Irwin proceed with complete replacement of the piping.

d. Recommend that complete replacement not be done.

FOR THE COMMANDER AND DIRECTOR:

Robert D. Neathammer

ROBERT D. NEATHAMMER
RPMA Team Leader

CF: (Faxed)
A. Houtzager, EHSC-HM-O
L. Layton, CEMP-MA
W. Perry, Ft. Irwin DEH
C. Kirk, EHSC-FB-S
J. Hovell, EHSC-FB-S
R. Karney, EHSC-FU-M
B. Wasserman, EHSC-FU-M
P. Brozek, CESPK-ED-T

TABLE I

Table showing costs of water pipe Leaks

PREFABRICATED

	LEAKS		FLOOR		WALL & CEILING		
DATES	**#WOs**	**Cost $**	**#WOs**	**Cost $**	**#WOs**	**Cost $**	**Total $**
Jun 84 - May 85	28	763	54	873	20	345	1,981
Jun 85 - May 86	42	2,524	45	1,414	26	669	4,607
Jun 86 - May 87	28	758	34	727	54	928	2,413
Jun 87 - May 88	65	1,769	68	2,094	41	2,338	6,201
Jun 88 - May 89	87	2,462	39	683	54	1,995	5,140
Jun 89 - May 90	104	4,870	42	2,793	81	2,715	10,378
Jun 90 - May 91	202	11,484	98	16,596	114	7,661	35,741
Totals	556	24,629	380	25,179	390	16,651	66,459

$332/PER UNIT FOR 7 YEARS
$154/PER UNIT FOR TOTAL FIRST 7 YEARS
$179/PER UNIT FOR 7TH YEAR

CONVENTIONAL

June 84 - May 91	109	3,928	70	8,590	216	5373	17,891

$124/PER UNIT FOR 7 YEARS

Table shows upper limit for costs due to leaks as only a few of the floor and wall/ceiling costs are due to leaks.

TABLE 2

(1)

PREFABRICATED HOUSING
(1 JUN 90 - 31 MAY 91)

UNIT NRS	WATER LINE REPAIR		FLOORING REPAIR		WALL & CEILING REPAIR		TOTAL COST $
	#TASKS	COST($)	#TASKS	COST($)	#TASKS	COST($)	
3800	2	98					98
3801	3	270	2	37	1	15	327
3802	4	204	4	103	1	149	456
3803	5	323	7	943	3	130	1,396
3804	4	434	2	2,253	1	616	3,303
3805	3	225	2	136			361
3806	4	106	2	34	2	151	291
3807	3	102	1	16	2	55	173
3809	1	52	1	11			63
3811	4	134	2	115	1	21	269
3812	5	395	3	352	2	168	915
3813	4	114	2	28	2	85	227
3814	2	117	1	62	2	29	208
3815			1	312			312
3816	1	54	2	33	1	9	96
3818	7	236	5	102	7	170	508
3820	4	106	1	143	2	44	294
3821	3	120	3	191	3	415	725
3822	4	390			2	123	513
3823					3	97	97
3824	4	313			1	20	333
3825	9	443	3	4,413	2	86	4,942
3826	5	382	2	304	4	212	898
3827	6	465	3	45	6	873	1,383
3828	2	132	2	53	2	234	420
3829	3	225	2	25	1	49	299
3831	2	51	1	12	2	55	119
3832	9	482	4	187	2	95	765
3833	10	549	2	86	6	885	1,520

PREFABRICATED HOUSING
(1 JUN 90 - 31 MAY 91)

UNIT NRS	WATER LINE REPAIR		FLOORING REPAIR		WALL & CEILING REPAIR		TOTAL COST $
	#TASKS	COST ($)	#TASKS	COST ($)	#TASKS	COST ($)	
3834	1	44	3	396			440
3835	5	181	1	16	3	110	307
3837	7	334	6	2,993	4	202	3,529
3839	4	306	5	186	2	53	545
3840	5	164			2	100	264
3841	6	300	4	110	2	498	908
3842	3	141			3	435	576
3843	6	504	3	72	5	183	760
3844	7	340	3	451	2	44	835
3845	2	187	3	321	3	158	667
3846	3	336	3	68			404
3848	3	172			1	13	186
3850	3	126	2	57	3	78	261
3851	1	146	1	33	2	265	444
3852	8	608	2	617			1,226
3853	1	45	1	27	1	11	83
3854	3	148	3	420	2	161	729
3855	4	88	3	50	6	114	252
3856	4	235	2	36	3	47	318
3857	8	302	4	95	6	347	744
3858	5	256	3	1,685	3	54	1,995
TOTALS	202	11,485	112	17,629	114	7,659	36,784

NOTE: FLOORING REPAIR INCLUDES CARPETING

APPENDIX B
Statement of Work for Work Order No. ER00140-1 dated 5 July 1991

WORK ORDER NO. ER00140-1 5 July 1991

STATEMENT OF WORK
FOR:

REPLACE PIPINGS (Bldg. 3804)
200 HOUSING AREA

DEPARTMENT OF THE ARMY
NATIONAL TRAINING CENTER
FORT IRWIN, CALIFORNIA

SCOPE OF WORK: The contractor shall remove necessary sheet rocks, existing domestic hot and cold water lines, defluoridated cold water line (RO water line), their fittings and valves, the contractor shall install new hot and cold water lines, defluoridated cold water line (RO water line), their fitting and valves, replace the sheet rocks. The contractor shall repair or fill holes, open ceilings, floors, other openings, paint to match the existing conditions according to drawing and specifications.

TABLE OF ATTACHMENTS:

SECTION	DESCRIPTION	PAGE
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1	General requirements	1 - 12
2050	Demolition	1 - 2
15003	Tests	1 - 2
15006	Valves	1 - 2
15007	Hangers and supports	1 - 2
15010	Pipe and pipe fittings	1 - 2
15400	Plumbing, general purpose	1 - 9
DRAWINGS	Title Sheet	Sht. T-1
	Site Plan	Sht. G-1
	Typ. Plate Cut & Piping Det's	Sht. P-1
	1st Floor Plumbing, Bldg. IV	Sht. P-2
	1st Floor Plumbing, Unit C	Sht. P-3
	1st Floor Plumbing, Bldg. BR	Sht. P-4
	2nd Floor Plumbing, Bldg. IV	Sht. P-5
	2nd Floor Plumbing, Unit C	Sht. P-6
	2nd Floor Plumbing, Unit BR	Sht. P-7

DIRECTORATE OF ENGINEERING AND HOUSING FORT IRWIN, CALIFORNIA

SECTION 2050

DEMOLITION

PART 1 GENERAL

1.1 The work includes removal of existing hot and cold water lines, defluoridated cold water line(RO water line) their fittings, valves as indicated on the drawings. Holes, open ceiling, floor, other openings, paint shall be filled or repair to match the existing conditions. All materials resulting removal work, except as indicated or specified otherwise, shall become the property of the Contractor and shall be removed from the limits of Government property. Rubbish and debris shall be removed from Government property daily unless otherwise directed so as to not allow accumulation inside or outside the building. Materials that cannot be removed daily shall be stored in areas specified by the Contracting Officer.

1.2 DUST CONTROL

The amount of dust resulting from demolition shall be controlled to prevent the spread of dust to occupied portions of building and to avoid creation of a nuisance in the surrounding area.

1.3 PROTECTION

1.3.1 Protection of existing work: Before beginning any cutting or removing work, the Contractor shall carefully survey the existing work and examine the drawings and specifications to determine the extent of the work. The Contractor shall take all necessary precautions to insure against damage to existing work to remain in place, to be reused, or to remain the property of the Government, and any damage to such work shall be repaired or replaced as approved by the Contracting Officer at no additional cost to the Government. The Contractor shall carefully coordinate the work of this section with all other work, construct and maintain shoring, bracing and supports, as required. The contractor shall insure that structural elements are not overloaded and be responsible for increasing structural supports or adding new supports as may be required as a result of any cutting, removal, or demolition work performed under any part of this contract.

1.3.2 Protection of buildings from the weather: The interior of the building and all materials and equipment shall be protected from the weather at all times.

1.3.3 Environmental Protection: All work and Contractor operations shall comply with the requirements of ENVIRONMENTAL PROTECTION.

1.4 BURNING: The use of burning at the project site for the disposal of refuse and debris will not be permitted.

PART 2 EXECUTION

2.1 EXISTING FACILITIES

2.1.1 Utility Services: Disconnections of utility services, with related equipments are included.

2.1.2 Filling: Holes, open ceilings and other hazardous openings shall be filled to match the existing conditions.

2.1.3 Disposition of material:

2.1.3.1 Title to materials: Title to all materials and equipment to be demolished, excepting Government salvage and historical items, is vested in the Contractor upon receipt of notice to preceed. The Government will not be responsible for the condition, loss or damage to such property after notice to proceed.

2.1.3.2 Material for Contractor Salvage: Material for salvage shall be stored as approved by the Contracting Officer. Salvage materials shall be removed from Government property before completion of the Contract. Material for salvage shall not be sold on the site.

2.1.3.3 Unsalvageable materials: Concrete, masonry, and other noncombustible materials other than concrete permitted to remain in place, shall be disposed in the disposal area.

2.1.3.4 Damaged items: Items damaged during removal or storage shall be repaired or replaced to match existing.

2.1.3.5 Clean-up:

2.1.3.5.1 Debris and rubbish: Debris and rubbish shall be removed from the work areas and similar excavations.

2.1.3.5.2 Debris Control: Debris shall be removed and transported in a manner as to prevent spillage on streets or adjacent areas.

2.1.3.5.3Regulations: Local regulations regarding hauling and disposal apply.

END OF SECTION

SECTION 15003

TESTS

PART 1 - GENERAL

1.1 DESCRIPTION

A. Description of tests:

1. Provide all labor, material, supplies and service for tests specified. Correct all defects appearing under test, and repeat tests until no defects are disclosed, leave equipment clean and ready for use.

2. Provide all necessary supplied, equipment, materials and labor for cleaning, testing, adjusting and starting up of equipment, make and remove all temporary piping connections required for tests and dispose of water and wastes after tests in manner satisfactory to Contracting Officer.

3. The completed work shall be adjusted to meet design requirements as specified and as indicated.

1.2 SUBMITTALS

Three copies of test reports shall be submitted to Contracting Officer.

PART 2 - EXECUTION

2.1 PROCEDURES

A. Pressure test cold and hot water lines to 120 psi for 2 hrs. Repair leaks and retest.

B. The Contracting Officer Representative must be informed at least two(2) working days prior to pressure testing.

C. Disinfection: Before acceptance of the piping system, each unit of the completed system shall be disinfected as specified. After pressure tests have been made, the unit to be disinfected shall be thoroughly flushed with water until all entrained dirt and mud have been removed before introducing the chlorinating material. The chlorinating material shall be either liquid chlorine, calcium hypochlorite, or sodium hypochlorite. The chlorinating material shall provide a dosage of not less than 50 ppm and shall be introduced into the lines in an approved man-

ner. The treated water shall be retained in the pipe at least 24 hours and shall produce not less than 10 ppm of chlorine throughout the line at the end of the retention period. All valves on the lines being disinfected shall be opened and closed several times during the contact period. The line shall then be flushed with clean water until the residual chlorine is reduced to less than 1.0 ppm. From several points in the unit, the Contracting Officer will take samples of water in properly sterilized containers for bacterial examination.

D. The Contracting Officer Representative must be informed at least two(2) working days prior to disinfected the piping system.

2.2 CLEANING AND ADJUSTING

A. Cleaning of piping systems:

1. Contractor shall clear the various systems of dirt, scale, oil, grease, waste and other foreign substances accumulated during the process of installation. All strainer screens should be removed, cleaned and replaced after the cleaning process, and cleaned after the flushing process.

2. Domestic water system: Flushed with post water until system is clean.

B. Adjusting:

After entire installation has been completed, make all required adjustments to shut-off valve, gate valve, temperature setting etc., until all performance requirements are met.

C. Cleaning:

Upon completion of the work, all fixtures, trimmings and equipment shall be thoroughly cleaned, polished and left in first class condition for final acceptance.

END OF SECTION

SECTION 15006

VALVES

PART 1 - GENERAL

1.1 DESCRIPTION

A. Related work specified elsewher:

Pipe and Pipe fitting

B. Design criteria:

1. Provide valves for all piping systems as specified and as indicated.

2. Install valves with best of workmanship, appearance and grouping so that all parts are readily accessible for maintenance.

1.2 SUBMITTALS

Manufacturer's literature:

1. Name of manufacturer and list of valves for each system.

2. Manufacturer's figure number for each type.

3. Type of valve and pressure rating.

1.3 PRODUCTS

1. Water Hammer Eliminator: Unit is factory prechared to 22 psig. max. working pressure 125 psig, max. temperature 200 degree F.

2. Gate Valves: Max. pressure ratings W.O.G. 200 psi, max. temperature 450 degree F. Nonrising stem, screw-in bonnet.

3. Check Valves: Max. pressure 200 psi, max. temperataure 450 degree F.

4. Wall Hydrants: Designed with valve seat inside building to prevent freezing, non-slip high impact plastic handle, brass body, copper tube, 3/4" garden hose thread outlet, length 6".

5. Angle Valve: Max. pressure 200 psi, max. temperature 450 degree F.

END OF SECTION

SECTION 15007

HANGERS AND SUPPORTS

PART 1 - GENERAL

1.1 DESCRIPTION

A. Related work specified elsewhere:

Pipe and pipe fittings

Valves

B. Description:

1. Provide hangers and supports for piping systems.

2. Provide inserts, brackets, anchors, stud welds, pipe clamps as specified or as required.

1.2 SUBMITTALS

A. Shop drawings and manufacturer's literature.

B. Constructed details of pipe supports.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Horizontal pipes:

1. Hangers and supports shall be hung from adequate solid rods, the lengths of which shall be adjustable.

2. Hanger rods shall be hung from suitable clips, beam clamps, stud welds, or inserts, as required.

3. Hanger and support spacing:

Horizontal copper pipes, maximum spacing as follows:

1/2" to 1"	5 ft.
1-1/4" and 1-1/2"	7 ft.

4. "Dielectric" material on hangers.

B. Miscellaneous supports:

1. Provide wall brackets and anchors where required in accordance with the best standard practices of the trade.

2. Provide all supplementary framing required for attachment of hanger, supports, and anchors. Fasten supplementary framing to structure in an approved manner. Supplementary framing of structural angle iron, channels and "I" beams properly designed to carry the weight of piping and its contents and to withstand any thrust exerted by the expansion or contraction of the piping.

3. Submit details of all hangers, anchors, supplementary framing including the proposed method of fastening of supplementary framing to the base building structure and all calculations used in determining the proposed fastening method.

4. All structural work shall conform to applicable building codes.

5. Supplementary framing shall be painted with one coat of rust preventive paint after installation under work of this Division.

C. All vertical pipe lines shall be supported, not hung at each floor with malleable iron or steel pipe clamps of ample size, bolted around the pipe.

END OF SECTION

SECTION 15010

PIPE AND PIPE FITTINGS

PART 1 - GENERAL

1.1 DESCRIPTION

A. Related work specified in other sections:

Valves

B. Description:

1. Provide pipe, fittings, accessories, for all piping systems indicated.

2. Piping includes pipe, fittings, nippled, unions, flanges etc.

1.2 QUALITY ASSURANCE

A. Requirements of regulatory agencies:

1. Pipe:

a. Copper pipe, type M, rigid ASTM-B88

b. CPVC pipe, schedule 80 Type IV, Grade 1 per ASTM D-1784.

1.3 SUBMITTALS

A. Material list of pipe and fitting.

B. Manufacturer's literature indicating compliance to specified requirements.

PART 2 - PRODUCTS

2.1 FABRICATION

A. The word "piping" means pipe, fittings, and nipples. No piping permanently closed up, furred in, or covered before inspection and approval.

B. All runs of piping to be made up using full length sections of pipe or lengths cut to fit. Offsets made with fittings, and pipes not to be bent. Pipe sizes not decreased from those indicated.

C. During construction, temporarily close open ends of pipes when necessary or required to prevent debris from entering piping systems.

2.2 MATERIAL

The following pipe to be used for systems:

A. Hot and Cold water lines: Copper pipe, Type M, rigid.

B. Defluoridated Cold Water Lines (RO water line): CPVC pipe, schedule .40 Per D. Kogan – 3-9-92 at 5547 H.

PART 3 - EXECUTION

3.1 INSTALLATION

Install this work in coordination with other work of Division 15 to provide a complete and acceptable system.

END OF SECTION

SECTION 15400

PLUMBING, GENERAL PURPOSE

PART 1 GENERAL

1.1 The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN NATIONAL STANDARDS INSTITUTE, INC. (ANSI)

ANSI A112.1.2	(1973; R 1979; Errata) Air Gaps in Plumbing Systems
ANSI A112.14.1	(1975) Backwater Valves
ANSI B1.20.1	(1983) Pipe Threads, General Purpose (Inch)
ANSI B16.18	(1984) Cast Copper Alloy Solder Joint Pressure Fittings
ANSI B16.22	(1980) Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ANSI Z21.10.1	(1987) Gas Water Heaters Vol I: Automatic Storage Water Heaters with Input of 75,000 BTU Per Hour or Less

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM B 42	(1988) Seamless Copper Pipe, Standard Sizes
ASTM B 88	(1988; Rev a) Seamless Copper Water Tube
ASTM B 641	(1988) Seamless and Welded Copper Distribution Tube (Type D)
ASTM D 638	(1989) Tensile Properties of Plastics
ASTM D 1785	(1988) Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedule 40, 80, and 120
ASTM D 2447	(1988) Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter
ASTM D 2466	(1988) Poly(Vinyl Chloride) (PVC)

	Plastic Pipe Fittings, Schedule 40
ASTM D 2564	(1988) Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings
ASTM D 2737	(1988) Polyethylene (PE) Plastic Tubing
ASTM D 3139	(1984) Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC. (ASHRAE)

ASHRAE 90A	(1980) Energy Conservation in New Building Design

AMERICAN SOCIETY OF SANITARY ENGINEERING (ASSE)

ASSE 1001	(May 1966; Rev Jul 1980) Pipe Applied Atmospheric Type Vacuum Breakers
ASSE 1003	(1964; Rev May 1981) Water Pressure Reducing Valves for Domestic Water Supply Systems

AMERICAN WATER WORKS ASSN (AWWA)

AWWA B300	(1987) Hypochlorites
AWWA B301	(1987) Liquid Chlorine
AWWA M20	(1973) Water Chlorination Principles and Practices

FEDERAL SPECIFICATIONS (FS)

FS TT-P-1536	(Rev A) Plumbing Fixture Setting Compound
FS TT-S-00230	(Rev C; Am 2) Sealing Compound, Elastomeric Type, Single Component for Calking, Sealing, and Glazing in Buildings and other Structures
FS TT-S-001543	(Rev A) Sealing Compound, Silicon Rubber Base for Calking, Sealing, and Glazing in Buildings and other structures

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY, INC. (MSS)

MSS SP-58	(1983) Pipe Hangers and Supports-Materials, Design and Manufature
MSS SP-69	(1983) Pipe Hangers and Supports-Selection and Application
MSS SP-73	(1986) Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Pressure Fittings
MSS SP-80	(1987) Bronze Gate, Globe, Angle and Check Valves

NATIONAL ASSN OF PLUMBING-HEATING-COOLING CONTRACTORS (NAPHCC)

NAPHCC-01	(1987) National Standard Plumbing Code

NATIONAL SANITATION FOUNDATION (NSF)

NSF Std 14	(Oct 1965; Rev thru Oct 1987) Plastic Piping System Components and Related Materials

PLASTIC PIPE INSTITUTE (PPI)

PPI 01	(1976; 1st Ed) Plastics Piping Manual

PLUMBING AND DRAINAGE INSTITUTE (PDI)

PDI-WH 201	(1977) Water Hammer Arresters

1.2 GENERAL REQUIREMENTS

1.2.1 Standard Products

Materials and equipment shall be the standard products of a manufacturer regularly engaged in the manufacture of the products. Items of equipment shall essentially duplicate equipment that has been in satisfactory use at least 2 years prior to bid opening.

1.2.2 Verification of Dimensions

The Contractor shall become familiar with details of the work, verify dimensions in the field, and advise the Contracting Officer of any discrepancy before performing any work.

1.2.3 Code

All plumbing work shall be in accordance with NAPHCC-01, unless otherwise stated.

1.3 SUBMITTALS

The following shall be submitted:

SD-31, Detail Drawings

Details drawings shall be submitted and shall consist of illustrations, schedules, performance charts, instructions, brochures, diagrams and other information to illustrate the requirements and operations of the system. Detail drawings shall be provided for the complete plumbing system and shall include piping layouts and locations of connections; dimensions for rough-in, foundation, and support points, schematic diagrams and wiring diagrams or connection and interconnection diagrams. Detail drawings shall indicate clearances required for maintenance and operation. Where piping and equipment are to be supported other than as indicated, details shall include loadings and proposed support methods.

SD-70, Test Reports

Upon completion and testing of the installed system, test reports shall be submitted in booklet form showing all field tests performed to adjust each component and all field tests performed to prove compliance with the specified performance criteria. Each test report shall indicate the final position of controls.

Test reports shall include the disinfected piping system reports.

SD-76, Certificates of Compliance

Where materials are specified to comply with requirements of AGA, or ASME, proof of such compliance shall be submitted.

PART 2 PRODUCTS

2.1 MATERIALS

Pipe fittings shall be compatible with the applicable pipe materials. Plastic pipe, fittings, and solvent cement shall meet NSF Std 14 and shall be NSF listed for the service intended. Plastic pipe, fittings and solvent cement used for water service shall bear the NSF seal "NSF-PW." Material containing lead shall not be used in any water system.

2.1.1 Pipe Joint Materials

Plastic solvent cement for PVC plastic pipe: ASTM D 2564 and ASTM D 2855.

2.1.2 Miscellaneous Materials

Miscellaneous materials shall conform to the following:

a. Water Hammer Arrester: PDI-WH 201.

b. Hypochlorites: AWWA B300.

c. Liquid Chlorine: AWWA B301

2.1.3 Hot and cold water lines: Copper pipe and fittings, Type M.

2.1.4 Defluoridated cold water line (RO water line): PVC pipe, Schedule 40.

2.2 PIPE HANGERS, INSERTS AND SUPPORTS

Pipe hangers, inserts and supports shall conform to MSS SP-58 and MSS SP-69.

2.3 VALVES

Valves shall be provided on supplies to equipment and fixtures. Valves in connection with runouts, risers, branches and mains shall be installed where indicated. Valves shall be gate valves, unless otherwise specified or indicated. Valves 2-1/2 inches and smaller shall be bronze, with threaded bodies for pipe and solder-type connections for tubing. Valves 3 inches and larger shall have flanged iron bodies and bronze trim. Pressure rating shall be based upon the spplication. Valves used for water service shall have the zinc content limited to no more than 6 percent for the stem, body, bonnet, wedge, or disk in contact with the fluid. Grooved end valves may be provided if the manufacturer certifies that the valves meet the performance requirements of applicable MSS standard.

Bronze Gate, Globe, Angle and Check Valves	MSS SP-80
Backwater Valves	ANSI A112.14.1
Water Pressure Reducing Valves	ASSE 1003

2.3.1 Water Hammer Eliminator: Unit is factory precharged to 22 psig. Max. working pressure is 125 psig, max. temperature is 200 degree F. Connection is 1/2" male NPT. Size 4-1/2" ht. X 3-3/8" dia.

2.3.2 Gate Valves: Max. pressure ratings W.O.G. 200 psi, Max. Temperature 450 degree F., Nonrising stem, screw-in bonnet.

2.3.3 Check Valves: Max. pressure 200 psi, max. temperature 450 degree F.

2.3.4 Wall Hydrants: Designed with valve seat inside building to prevent freezing, non-slip high impact plastic handle, brass body, copper tube, 3/4" garden hose thread outlet, length 6".

2.3.5 Angle Valves: Max. pressure 200 psi, max. temperature 450 degree F.

PART 3 EXECUTION

3.1 Fire Wall Penetrations

Metallic pipe shall be used through the fire wall to a point at least 6 inches on both sides of the wall.

3.2 Floor/Ceiling Penetrations

Metallic Pipe shall be used through the floor/ceiling from at least 6 inches below the ceiling to at least 6 inches above the floor.

3.3 Water Pipe, Fittings and Connections

3.3.1 Utilities

The piping shall be extended to fixtures, outlets and equipment. The hot-water and cold-water piping system shall be arranged and installed to permit draining. The supply line to each item of equipment or fixture, except faucets, flush valves, or other control valves which are supplied with integral stops, shall be equipped with shut-off valve to enable isolation of the item for repair and maintanance without interfering with operation of other equipment or fixtures. Supply piping to fixtures, faucets, hydrants, shower heads, and flush valves shall be anchored to prevent movement.

3.3.2 Cutting and Repairing

The work shall be carefully laid out in advance, and unnecessary cutting of construction shall be avoided. Damage to building, piping, wiring, air ducts or equipment as a result of cutting shall be repaired by mechanics skilled in the trade involved.

3.3.3 Protection to Fixtures, Materials, and Equipment

Pipe openings shall be closed with caps or plugs during installation. Fixtures and equipment shall be tightly covered and protected against dirt, water, chemicals, and mechanical injury. Upon completion of the work, the fixtures, materials, and equipment shall be thoroughly cleaned, adjusted, and operated. Safety guards shall be provided for exposed rorating equipment.

3.3.4 Mains, Branches, and Runouts

Piping shall be installed as indicated. Pipe shall be accurately cut and worked into place without springing or forcing. Care shall be taken not to weaken structural portions of the building. Aboveground piping shall run parallel with the lines of the building, unless otherwise indicated. Branch pipes from service lines may be taken from top, bottom, or side of main, using crossover fittings required by structural or installation conditions. Supply pipes, valves, and fittings will be kept a sufficient distance from other work and other services to permit not less than 1/2 inch between finished covering on the different services. Bare water lines shall not bear directly against building structural elements so as to transmit sound to structure or to prevent flexible movement of the lines. Changes in pipe sizes shall be made with reducing fittings. Use of bushings will not be permitted. Change in direction shall be made with fittings, except that bending of pipe 4 inches and smaller will be permitted, provided a pipe bender is used and wide sweep bends are formed. The center-line radius of bends shall be not less than 6 diameters of the pipe. Bent pipe showing kinks, wrinkles, flattening, or other malformations will not be acceptable.

3.3.5 Expansion and Contraction of Piping

Allowance shall be made throughout for expansion and contraction of water pipe. Each hot-water and hot-water circulation riser shall have expansion loops where requied. Risers shall be securely anchored as requied to force expansion to loops. Branch connections from risers shall be made with ample swing or offset to avoid undue strain on fittings or short pipe lenghts. Horizontal runs of pipe over 50 feet in length shall be anchored to the wall or the supporting construction about midway on the run to force expansion, evenly divided, toward the ends. Sufficient flexibility shall be provided on branch runouts from mains and risers to provide for expansion and contraction of piping. Flexibility shall be provided by installing one or more turns in the line so that piping will spring enough to allow for expansion without straining.

3.3.6 Copper Tube

Joints for copper tubing shall be made with soldered or brazed fittings. Solder shall consists of 95 percent tin and 5 percent antimony. Tubes shall be cut square and reamed to remove burrs. Outside surface of the tube where engaged in the fitting, and inside surface of the fitting in contact with the tube, shall be cleaned with an abrasive material before soldering. Solder joints shall be made with flux and wire form or paste-type solder. The flux for solder shall be mildly corrosive liquid or petroleum-based paste containing chlorides or zinc and ammonia. Core

solder shall not be used. Excess solder shall be wiped from joint before solder hardens. Joints in copper tube 2-1/2 inches and larger shall be made with heat applied uniformly around the entire circumference of the tube and fittings by a multiflame torch. Excess solder flux on the inside surface of the joint shall be avoided. Copper tube joints under floor slabs shall be brazed.

3.3.7 Water Hammer Arresters

Commercial-type water hammer arresters shall be provided on hot and cold water supplies and shall be located as generally indicated, with precise location and sizing to be in accordance with PDI-WH 201. Water hammer arresters, where concealed, shall be accessible by means of access doors or removable panels. Commercial-type water hammer arresters shall be in accordance with PDI-WH 201. Vertical capped pipe columns will not be permitted.

3.3.8 Dissimilar Pipe Materials

Connections to water heaters and connections between ferrous and copper pipe shall made with dielectric unions or flanges. Connecting joints between plastic and metallic pipe shall be made with transition fitting for the specific purpose.

3.3.9 Pipe Sleeves and Flashing

Pipe sleeves shall be furnished and set in their proper and permanent location.

3.3.10 Fire Seal

Where pipes pass through fire walls, fire-partitions, fire-rated pipe chase walls or floors above grade, a fire seal shall be provided.

3.4 Supports

3.4.1 General

Hangers used to support piping 2 inches and larger shall be fabricated to permit adequate adjustment after erection while still supporting the load. Pipe guides and anchors shall be installed to keep pipes in accurate alignment, to direct the expansion movement, and to prevent buckling, swaying, and undue strain. All piping subjected to vertical movement when operating temperature exceed ambient temperatures, shall be supported by variable spring hangers and supports or by constant support hangers. In the support of multiple pipe runs on a common base member, a clip or clamp shall be used where each pipe crosses the base support member. Spacing of the base support members shall

not exceed the hanger and support spacing required for an individual pipe in the multiple pipe run.

3.4.2 Pipe Supports and Structural Bracing, Seismic Requirements

All piping and attached valves shall be supported and braced to resist seismic loads. Structural steel required for reinforement to properly support piping, headers, and equipment but not shown shall be provided.

3.4.3 Pipe Hangers, Inserts, and Supports

Pipe hangers, inserts and supports installation shall conform to MSS SP-58 and MSS SP-69.

3.4.4 Escutcheons

Escutcheons shall be provided at finished surfaces where bare piping, exposed to view, passes through floors, walls, or ceilings, except in boiler, utility, or equipment rooms. Escutcheons shall be fastened securely to pipe or pipe covering and shall be satin-finish, corrosion-resisting steel, polished chromium-plated zinc alloy, or polished chromium-plated copper alloy. Escutcheons shall be either one-piece or split-pattern, held in place by internal spring tension or setscrew.

3.4.5 Tests and Disinfection

Shall comply to Section 15003, Tests.

END OF SECTION

APPENDIX C
Pre-Manufactured Housing Contractor Plumbing Submittal

E / 1	LENNOX MODEL C5-495-FF W/ LB 25778-CG EXPANSION VALVE KIT FIELD INSTALLED. INSTALL OV FURNACE IN SHEET METAL PLENUM. RUN 3/4" CONDEN: DRAIN FROM COIL PAN THRU FL. JTS. TO BUILDING EXTERIOR
EF / 1 (2)	BATHROOM EXHAUST FAN - HVI CERTIFIED - 60 CFM CAP. - 3.5 SONES BROAN MODEL 689 - 2400 R.P.M .85 AMPS - 1/100 H.P. MOTOR WITH VERTICAL OR HORIZONTAL DISCHARGE AS REQUIRED. INSTALL W/ BACKDRAFT DAMPER & CAP
RH / 1 (2)	KITCHEN RANGE HOOD - HVI CERTIFIED - 5.5 SONES VERT. - BROAN MODEL 42000 - 7"Ø OUTLET - 190 CF @ .1 PS WITH 2.5 AMP - 120 V - 1Ø MOTOR AND 639 C 649 ROOF OR WALL CAP AS APPLICABLE. INSTALL W/ BACKDRAFT DAMPER & CAP

LEVITT HOMES, INC.

10800 Kalama River Rd., Fountain Valley, CA 92708. 714 962-7776

PRINTED ON
1983

BULB
DOOR
AIR
D ON

REVISION	DATE	DESCRIPTION	BY
1	26 JULY 83	CORPS OF ENGINEERS REVISION	R
2	5/13/83	REVISED EQUIPMENT SCHEDULE	MC

CORPS OF ENGINEERS, U.S. ARMY
LOS ANGELES DISTRICT
APPROVED
(except for errors & omissions)

AUG 10 1983
FOR THE CONTRACTING OFFICER
AUTHORIZED REPRESENTATIVE

ACTUS CORP.

103 CAMINO ORUGA BOX 3570 NAPA, CA 94558

DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

DESIGNED J.J.T.

DRAWN M.C.

CHECKED J.J.T.

FORT IRWIN, CALIFORNIA
200 MANUFACTURED/FACTORY BUILT FAMILY HOUSING UNITS FY-82

FIRST & SECOND FLOOR H.V.A.C. PLANS
UNIT "A"

SUBMITTED
William B. Faul
RCE 22981 3-14-83

DATE APPROVED

SCALE:

SPEC. No. 6390-SP

SHEET 72 M-1 OF 86

FILE No. 238-25-297

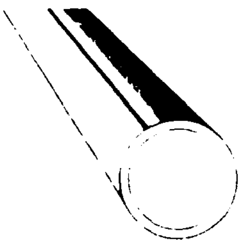
QEST A total polybutylene system for the professional plumber.

Qest offers the professional plumber a practical plastic hot cold pressure plumbing system for every kind of job new construction remodeling and repair. You can rely on practical Qest Systems because they were patented by a Master Plumber to meet the needs of the plumbing professional. Each system has been thoroughly tested and time proven, and they meet all national standards, agency approvals and many state and local codes.

The key word for Qest Systems is "efficiency." One man can easily carry a 1000' roll of ½" polybutylene tubing (47 pounds). And because polybutylene is flexible (at all temperatures) it can be installed in long lengths with a minimum number of joints and elbows. Here are just a few additional advantages offered by Qest Systems.

- TROUBLE-FREE POLYBUTYLENE
  - No Corrosion
  - No Electrolysis
  - The Best Tubing for Worst Water Conditions
- CRIMP AND THREAD CONNECTIONS
  - No Exotic Parts to Fail
  - No Solvents, Bonding Agents or Glues Used.
  - No Solder, Flux or Gas Used
  - More Positive Connections, Quicker, Easier
- LOW HEAT CONDUCTIVITY
  - Low Temperature Loss. Hot Stays Hot, Cold Stays Cold
  - Eliminates MOST Water Hammer Conditions

Hot/cold polybutylene piping



Qest HOT COLD polybutylene piping's versatility makes it perfect for many residential, commercial and industrial applications. It not only meets ASTM Standards, but goes well beyond these requirements. QEST Polybutylene will handle all nominal temperatures and pressures for residential potable water systems. Chemical resistance chart available on request.

Because Qest polybutylene tubing stays flexible at all temperatures, it's easier to lay out and rough in winter or summer.

Qest polybutylene tubing is inert. Nothing sticks to it, not even the "super glues." What this means is that it resists mineral buildup, rust, corrosion, and electrolysis.

And Qest polybutylene tubing is adaptable besides being a superior system when used in conjunction with any of the Qest systems. Further, HOT COLD polybutylene piping can be connected to galvanized, copper, and CPVC Systems with standard Qest fittings. No special transition fitting is required. Qest Acetal fittings also make excellent, low-cost dielectric connections.

See pages 6-7

Cold water service polybutylene piping

Qest BIG BLUE Polybutylene Pipe and Tubing is ideal for cold water service applications. It offers the distinct advantages of polybutylene, including extra strength, unusual flexibility and super toughness.

BIG BLUE is ideal for pumps, irrigation, feed lot lines and a host of other cold water jobs.

BIG BLUE Polybutylene Pipe and Tubing is chemically inert in soils and resists corrosion, lime-up and bacteria.

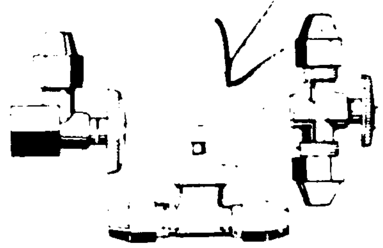
Qest corrosion resistant BIG BLUE is available in Copper Tube Size (CTS) per ASTM D-2666 - Iron Pipe Size (IPS) per ASTM D-2662. Both grades are for 160 pound service at 73°F. BIG BLUE CTS is available in [illegible] and 2 nominal I.D. sizes and BIG BLUE IPS in [illegible] and 2 nominal sizes. Standard coil lengths are 100', 200', 300' and 500'.

The 250 pound service at 73°F is also available in CTS [illegible] and 2 nominal I.D. sizes.

BIG BLUE Pipe and tubing have been approved by the American Water Works Assoc. and National Sanitation Foundation (NSF 14), IAPMO (UPC), BOCA and SBCC.

See pages 8-9

Acetal valves



Qest offers several types of Acetal valves including angle and straight pattern stop valves, and in-line globe valves. The unique design of the angle stops, in particular, make them highly applicable as washing machine valves and tank drains as well as fixture shut-offs.

Qest stop valves are engineered to eliminate common problems associated with ordinary brass valves. First of all, because they're made from Acetal, there's no liming up or corrosion. Less than one full turn opens or closes the valve. Next, female valves that connect to galvanized or chrome nipples, have a Qest "Magic Seal" cone that has been factory inserted in the female end. This eliminates need for pipe dope or tape and the problem of expansion leaks.

Qest in-line globe valves feature a rising stem design. O-Ring seals eliminate any packing problems.

See pages 22-23

And, polybutylene supply tubes

Qest puts an end to the troublesome job of fitting water connections to faucets or toilets with their polybutylene supply tubes.

They're tough, durable and most importantly they're flexible. They turn tight quarter bends into fast and easy connections. Qest supply tubes fit any compression valve or fitting.

Available in [illegible] O.D. and [illegible] O.D. sizes in all popular lengths.

See pages 26-27

CONTRACT NO. DACA05-83-C-0033

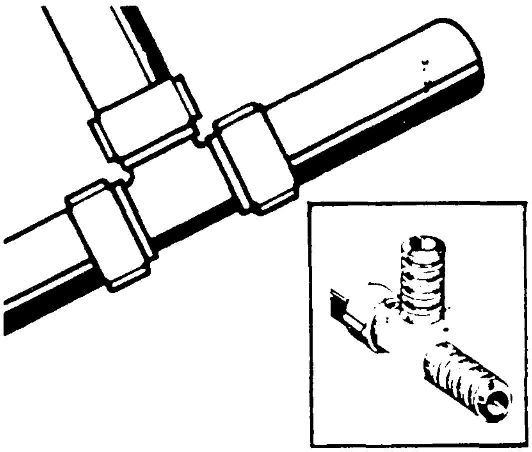
SUBMITTAL NO. 21

ITEM NO. 15

200 Manufactured/Factory-Built Family Housing Units, FY-82 Fort Irwin, California

And, there's a QEST fitti ng

. . . production, pre-fabricatior or



COPPER FITTINGS

QICK/SERT I SYSTEM

Designed for new construction or production plumbing. QICK SER 's the original Qest insert fitting for Polybutylene plumbing systems. QICK ERT I copper and brass barbed fittings must be used with copper crimp
QICK SERT I, like QICK SERT II, eliminates the need for solvents chemicals, solder and flame . . . it's a "no sweat" plumbing metho eyed to the demand of reduced plumbing costs.

Crimping tools and copper rings are interchangeable between Q ERT I and QICK SERT II. QICK SERT I offers fast, efficient installatior roper techniques and correct tool use are readily learned by Apprentic Journeymen. Installation is neat and professionally satisfying and accepted behind-the-wall.

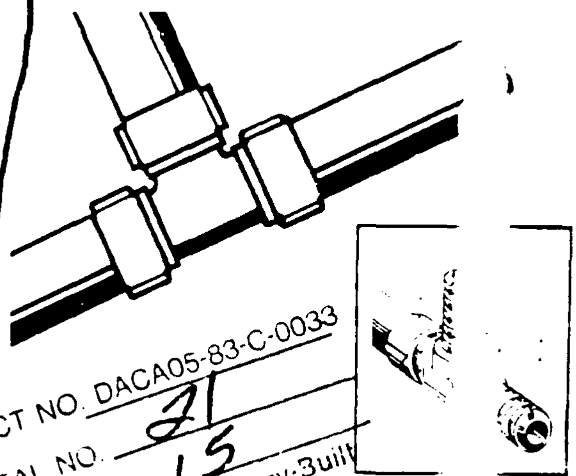
BARB FITTINGS AND CRIMP RINGS GO BEHIND THE WALL

QICK/SERT II SYSTEM

Designed specifically for new construction or major addition plumbing jobs QICK SERT II is a system utilizing compact Acetal* fittings and crimp rings that offer excellent flow characteristics. It eliminates the need for solvents, chemicals, solder . . . it's truly a "no sweat" system.

QICK SERT II offers the plumber other advantages, too! For instance, it provides major installed cost savings over conventional materials and polybutylene systems using compression type connections. Installation is neat and professional looking. There's also QICK SERT II's fast, efficient installation with positive connections suitable for behind-the-wall installations.

And, Qest's precision crimp tools have proved better and more reliable than other tool systems.



CONTRACT NO. DACA05-83-C-0033
SUBMITTAL NO. 21
ITEM NO. 15
Factory-Built ... 32
California

ACETAL FITTINGS

WHICH BARB FITTING AND WHICH CRIMP RING SHOULD YOU USE?

QICK SERT II Acetal fittings can be used with either copper crimp rings or aluminum crimp rings. Choice of copper or aluminum rings is often a matter of preference. Some contractors feel they obtain greater "strength" and "bite" with copper rings. Others prefer the economy of aluminum.

Aluminum rings should not be used with copper and brass fittings. (Copper rings are intended for these applications.)

The use of copper fittings vs. Acetal fittings is often a matter of personal preference. There is a cost premium for copper over Acetal mainly because of raw material pricing. Some installers feel they get a better "bite" in the connection with copper fittings, v when working in very cold weather. Others feel Acetal fitt e a neater appearing job because the color of the fittings e Polybutylene tube color are the same. There is a n butt-match between the Acetal fitting and the Polybuty be O.D. Preferences of local inspectors can influence a co rs choice.

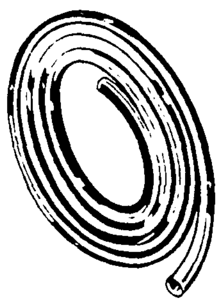
NOTE: QICK SERT I copper fittings must be used ny closed-loop or recirculating system.

In any area where sweat fittings are also being d, considerable care should be taken to keep any flux or a from contact with Acetal fittings and valves. Also avoid ng Acetal parts with flame or conducted heat from sweat con s

QEST POLYBUTYLENE

MANUFACTURED TO ASTM-D3309 180° AT 100 PSI

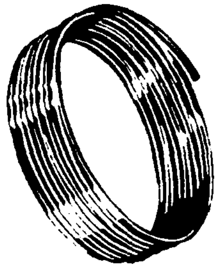
SILVER COILS



CAT. NO.	NOMINAL SIZE INSIDE DIA.	SIZE OUTSIDE DIA.	FT. COIL	LIST PRICE PER COIL
Q1PC100G	1/4	3/8	100	20.50
Q1PC1000G	1/4	3/8	1000	205.00
Q2PC100G	3/8	1/2	100	22.90
Q2PC500G	3/8	1/2	500	114.50
Q2PC1000G	3/8	1/2	1000	229.00
Q3PC100G	1/2	5/8	100	25.50
Q3PC500G	1/2	5/8	500	127.50
Q3PC1000G	1/2	5/8	1000	255.00
Q4PC100G	3/4	7/8	100	46.60
Q4PC500G	3/4	7/8	500	233.00
Q5PC100G	1	1 1/8	100	80.00
Q5PC300G	1	1 1/8	300	240.00

WARNING:
Like all plastic materials, Polybutylene should not be stored or installed in areas exposed to sunlight.

SILVER CAPILLARY/ DRAIN TUBING



CAT. NO.	NOMINAL SIZE INSIDE DIA.	SIZE OUTSIDE DIA.	FT. COIL	LIST PRICE PER COIL
QOPC50G	1/8	1/4	50	9.50
QOPC100G	1/8	1/4	100	19.00
QOPC1000G	1/8	1/4	1000	190.00

NOTE: 1/8" Tubing not covered under ASTM-D3309-81.

WARNING:
Like all plastic materials, Polybutylene should not be stored or installed in areas exposed to sunlight.

CONTRACT NO. DACA05-83-C-0023
SUBMITTAL NO. 21
ITEM NO. 15
200 Manufactured/Factory-Built
Family Housing Units, FY-82
Fort Irwin, California

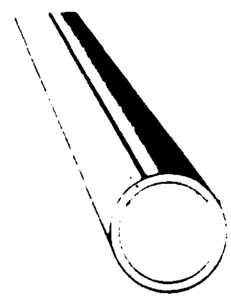
HOT/COLD TUBING

SILVER

STRAIGHT LENGTHS

10 FOOT

CAT. NO.	NOMINAL SIZE INSIDE DIA.	SIZE OUTSIDE DIA.	FT. BUNDLE	LIST PRICE PER 10 FT.
Q1PS10G	1/4	3/8	1000	2.05
Q2PS10G	3/8	1/2	1000	2.29
Q3PS10G	1/2	5/8	1000	2.55
Q4PS10G	3/4	7/8	500	4.66
Q5PS10G	1	1 1/8	500	8.00



20 FOOT

CAT. NO.	NOMINAL SIZE INSIDE DIA.	SIZE OUTSIDE DIA.	FT. BUNDLE	PER 20 FT.
Q1PS20G	1/4	3/8	1000	4.10
Q2PS20G	3/8	1/2	1000	4.58
Q3PS20G	1/2	5/8	1000	5.10
Q4PS20G	3/4	7/8	500	9.32
Q5PS20G	1	1 1/8	300	16.00

WARNING:
Like all plastic materials, Polybutylene should not be stored or installed in areas exposed to sunlight.

POLYBUTYLENE STORAGE—WARNING

Like most plastic materials, all polybutylene is subject to ultraviolet (UV) deterioration and must not be exposed to sun light, either direct or indirect. Storage outside is not recommended but if this becomes necessary, the tubing must be covered with a material which will protect it from ultraviolet light. Failure to do so will void the warranty.

CUTTING POLYBUTYLENE

Polybutylene is easy to cut with many types of cutting tools. Hacksaws, pruning shears, molding shears and pocket knives are often used for an occasional cut. The tube surface must be cut, not indented (with a dull tool). Professional and production work is best handled with ratchet type cutters. (See QPC 75 above) NOTE: Copper tube rotary cutters will not cut Polybutylene unless equipped with a special PB blade. All cuts should be reasonably straight and even and free of chips and slivers.

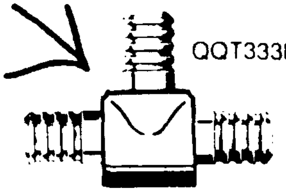
CONTRACT NO. DACA05-83-C-0033
SUBMITTAL NO. 21
ITEM NO. 15
200 Manufactured/Factory-Built
Family Housing Units, FY-82
Fort Irwin, California

QICK/SERT II

ACETAL INSERT FITTINGS

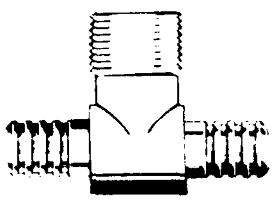
Rings are not included in the price of the fittings.

CONTRACT NO. DACA05-83-C-0033
SUBMITTAL NO. 21
ITEM NO. 15
200 Manufactured/Factory-Built
Family Housing Units, FY-82
Fort Irwin, California



QQT333B

QQT333BBT



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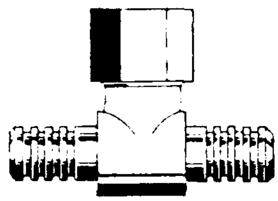
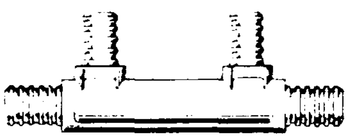
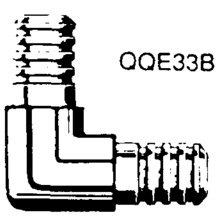


QQM4433B

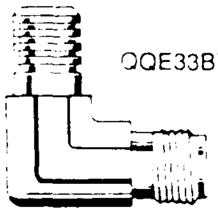


ACETAL TEES

CAT. NO.	DESCRIPTION	SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QQT222B	Tee	⅜ Barb	100	53	500
QQT223B	Tee	⅜ Barb × ⅜ Barb × ½ Barb	100	53	500
QQT322B	Tee	½ Barb × ⅜ Barb × ⅜ Barb	100	53	500
QQT323B	Tee	½ Barb × ⅜ Barb × ½ Barb	100	53	500
QQT332B	Tee	½ Barb × ½ Barb × ⅜ Barb	[illegible]	53	500
QQT333B	Tee	½ Barb	[illegible]	53	500
QQT334B	Tee	½ Barb × ½ Barb × ¾ Barb	50	76	250
QQT422B	Tee	¾ Barb × ⅜ Barb × ⅜ Barb	50	76	250
QQT432B	Tee	¾ Barb × ½ Barb × ⅜ Barb	50	76	250
QQT433B	Tee	¾ Barb × ½ Barb × ½ Barb	50	76	250
QQT434B	Tee	¾ Barb × ½ Barb × ¾ Barb	50	76	250
QQT442B	Tee	¾ Barb × ¾ Barb × ⅜ Barb	50	76	250
QQT443B	Tee	¾ Barb × ¾ Barb × ½ Barb	50	76	250
QQT444B	Tee	¾ Barb	50	76	250
QQT223BBT	Male Tee	⅜ Barb × ⅜ Barb × ½ MPT	100	60	500
QQT333BBT	Male Tee	½ Barb × ½ Barb × ½ MPT	100	60	500
QQT443BBT	Male Tee	¾ Barb × ¾ Barb × ½ MPT	100	75	500
QQT333BBS	Female Swivel Tee	½ Barb × ½ Barb × ½ FPT Swivel	100	1 52	500
QQM3333B	Manifold Tee	½ Barb	25	1 40	250
QQM4333B	Manifold Tee	¾ Barb × ½ Barb × ½ Barb × ½ Barb	25	1 53	250
QQM4433B	Manifold Tee	¾ Barb × ¾ Barb × ½ Barb × ½ Barb	25	1.85	250
QQM4444B	Manifold Tee	¾ Barb	25	2.01	250



QQE33B



QQE33BT

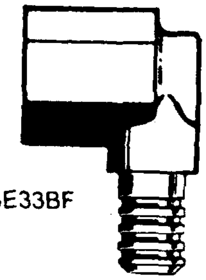
ACETAL ELBOWS

CAT. NO.	DESCRIPTION	SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QQE22B	Elbow	⅜ Barb	100	44	500
QQE33B	Elbow	½ Barb	100	44	500
QQE43B	Elbow	¾ Barb × ½ Barb	50	62	[illegible]
QQE44B	Elbow	¾ Barb	50	62	250
QQE22BT	Male Elbow	⅜ Barb × ⅜ MPT	100	51	[illegible]
QQE23BT	Male Elbow	⅜ Barb × ½ MPT	100	51	500
QQE32BT	Male Elbow	½ Barb × ⅜ MPT	100	51	500
QQE33BT	Male Elbow	½ Barb × ½ MPT	50	51	250
QQE34BT	Male Elbow	½ Barb × ¾ MPT	50	72	250
QQE44BT	Male Elbow	¾ Barb × ¾ MPT	50	72	250
QQE45BT	Male Elbow	¾ Barb × 1 MPT	50	1 30	250

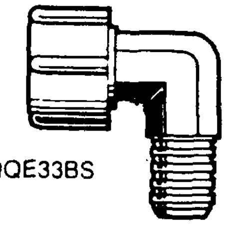
ACETAL

FEMALE ELBOWS

CAT. NO.	DESCRIPTION	SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QQSE23BF	Female Elbow	⅜ Barb × ½ FPT (w seal)	50	95	500
QQSE33BF	Female Elbow	½ Barb × ½ FPT (w seal)	50	95	500
QQSE44BF	Female Elbow	¾ Barb × ¾ FPT (w seal)	50	1.64	250
QQDE23BF	Female Drop Ear Elbow	⅜ Barb × ½ FPT (w seal)	50	1.10	500
QQDE33BF	Female Drop Ear Elbow	½ Barb × ½ FPT (w seal)	50	1.12	500
QQDE44BF	Female Drop Ear Elbow	¾ Barb × ¾ FPT (w seal)	50	1.77	250
QQE23BS	Swivel Female Elbow	⅜ Barb × ½ FPT Swivel (w seal)	50	1.26	500
QQE33BS	Swivel Female Elbow	½ Barb × ½ FPT Swivel (w seal)	50	1.28	500
QQE34BS	Swivel Female Elbow	½ Barb × ¾ FPT Swivel (w seal)	25	2.18	250
QQE44BS	Swivel Female Elbow	¾ Barb × ¾ FPT Swivel (w seal)	25	2.18	250



QQSE33BF



QQE33BS

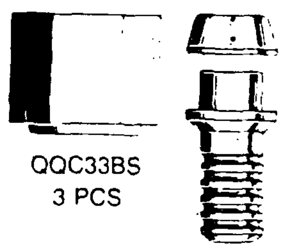
ACETAL

COUPLINGS AND ADAPTERS

CAT. NO.	DESCRIPTION	SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QQC22B	Coupling	⅜ Barb	100	.24	500
QQC32B	Coupling	½ Barb × ⅜ Barb	100	.25	500
QQC33B	Coupling	½ Barb	100	25	500
QQC43B	Coupling	¾ Barb × ½ Barb	50	.42	250
QQC44B	Coupling	¾ Barb	50	.42	250
QQC22BT	Male Adapter	⅜ Barb × ⅜ MPT	100	.45	500
QQC23BT	Male Adapter	⅜ Barb × ½ MPT	100	.45	500
QQC32BT	Male Adapter	½ Barb × ⅜ MPT	100	45	500
QQC33BT	Male Adapter	½ Barb × ½ MPT	100	.48	500
QQC34BT	Male Adapter	½ Barb × ¾ MPT	50	57	250
QQC44BT	Male Adapter	¾ Barb × ¾ MPT	50	57	250
QQC45BT	Male Adapter	¾ Barb × 1 MPT	50	.82	250
QQC44BA	Trans. Coupling Qicktite Compression	¾ Barb × ¾ Nom	25	2.01	250
QQC33BS	Female Swivel Adapter	½ Barb × ½ FPT Swivel	100	.60	500
QQC34BS	Female Swivel Adapter	½ Barb × ¾ FPT Swivel	50	89	250
QQC44BS	Female Swivel Adapter	¾ Barb × ¾ FPT Swivel	50	86	250

QQC33B

QQC33BT



QQC33BS
3 PCS

CONTRACT NO. DACA05-83-C-0033

SUBMITTAL NO. 21

ITEM NO. 15

200 Manufactured/Factory-Built
Family Housing Units, FY-82
Fort Irwin, California

QICK/SERT II

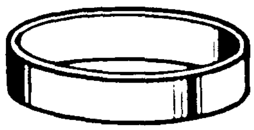
SUBMITTAL NO. 21
ITEM NO. 15
200 Manufactured/Factory-Built
Family Housing Units, FY-82
Fort Irwin, California

ACETAL

TEST PLUGS

CAT. NO.	DESCRIPTION-SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QQTP3B	Plug ½	100	24	1000
QQTP4B	Plug ¾	100	32	1000

CRIMP RINGS • TOOLS & GAUGE
FOR QICK/SERT I & QICK/SERT II SYSTEMS

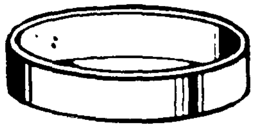


NOTE:
Rings are not included in price of individual fittings

ALUMINUM

CRIMP RINGS

CAT. NO.	DESCRIPTION-SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QCR2	Ring ⅜	100	.0611	1000
QCR3	Ring ½	100	.0713	1000
QCR4	Ring ¾	100	.0767	1000



NOTE:
Rings are not included in price of individual fittings.

COPPER

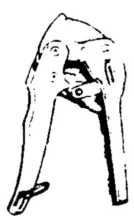
CRIMP RINGS

CAT. NO.	DESCRIPTION-SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QCR2C	Ring ⅜	100	110	1000
QCR3C	Ring ½	100	140	1000
QCR4C	Ring ¾	100	170	500

WHEN TO USE COPPER OR ALUMINUM RINGS-

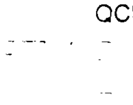
Choice of ring material is largely personal preference. See explanation bottom of page 4.

TOOLS



QPC75

QCRT3SP



QC43SP

NOTE: Frequent gauging of crimp joints is recommended.

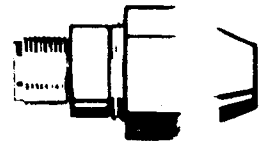
CAT. NO.	DESCRIPTION-SIZE	LIST PRICE EACH
QC43SP	Sizing Gauge for ⅜-½ & ¾ Crimp	3.00
QCRT2SP	⅜ Crimping Tools	90.00
QCRT3SP	Crimping Tools	90.00
QCRT43SP	Combination ½ and ¾ Crimping Tools	90.00
QPC75	¼ OD to 1⅛ OD Tube Cutter	19.65

ACETAL

COUPLING ADAPTERS

CAT. NO.	DESCRIPTION	FOR NOM. TUBE SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QACA11M	Male Coupling Adapter	1/4 × 1/4 MPT	25	1.50	250
QACA12M	Male Coupling Adapter	1/4 × 3/8 MPT	25	1.50	250
QACA13M	Male Coupling Adapter	1/4 × 1/2 MPT	25	1.50	250
QACA21M	Male Coupling Adapter	3/8 × 1/4 MPT	25	1.50	250
QACA22M	Male Coupling Adapter	3/8 × 3/8 MPT	25	1.50	250
QACA23M	Male Coupling Adapter	3/8 × 1/2 MPT	25	1.50	250
QACA31M	Male Coupling Adapter	1/2 × 1/4 MPT	25	1.96	250
QACA32M	Male Coupling Adapter	1/2 × 3/8 MPT	25	1.96	250
QACA33M	Male Coupling Adapter	1/2 × 1/2 MPT	25	1.73	250
QACA34M	Male Coupling Adapter	1/2 × 3/4 MPT	10	1.84	250
QACA43M	Male Coupling Adapter	3/4 × 1/2 MPT	10	1.84	250
QACA44M	Male Coupling Adapter	3/4 × 3/4 MPT	10	2.34	250
QACA45M	Male Coupling Adapter	3/4 × 1 MPT	5	2.47	100
QACA53M	Male Coupling Adapter	1 × 1/2 MPT	5	3.00	100
QACA54M	Male Coupling Adapter	1 × 3/4 MPT	5	3.00	100
QACA55M	Male Coupling Adapter	1 × 1 MPT	5	3.00	100
QACA56M	Male Coupling Adapter	1 × 1 1/4 MPT	5	3.24	100

NOTE: Acetal MPT is not recommended for mating to metal FPT.



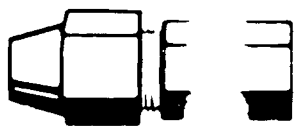
CONTRACT NO. DA 05-83-C-0C
SUBMITTAL NO.
ITEM NO.
200 Manufactur Factory-Bu
Family Housin Units, FY-8
Fort Irwin, California

ACETAL

FEMALE ADAPTERS

CAT. NO.	DESCRIPTION	FOR NOM. TUBE SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QAFA33F	Female Adapter	1/2 × 1/2 FPT	25	1.61	250
QAFA34F	Female Adapter	1/2 × 3/4 FPT	10	2.08	250
QAFA44F	Female Adapter	3/4 × 3/4 FPT	10	2.27	250
QAFA45F	Female Adapter	3/4 × 1 FPT	5	2.54	100
QAFA54F	Female Adapter	1 × 3/4 FPT	5	2.89	100
QAFA55F	Female Adapter	1 × 1 FPT	5	3.00	100

NOTE: Refer to page 20 for additional adapter QFNCR Series.



ACETAL

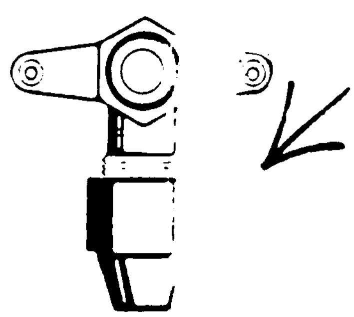
FEMALE ELBOWS

CAT. NO.	DESCRIPTION	FOR NOM. TUBE SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QASE23F	Female Elbow	3/8 × 1/2 FPT	25	1.73	250
QASE33F	Female Elbow	1/2 × 1/2 FPT	25	1.84	250

ACETAL

FEMALE D.E. ELBOWS

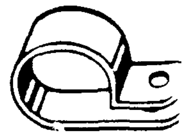
CAT. NO.	DESCRIPTION	FOR NOM. TUBE SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QADE23F	Drop Ear Elbow	3/8 × 1/2 FPT	25	2.00	250
QADE33F	Drop Ear Elbow	1/2 × 1/2 FPT	25	2.11	250
QADE34F	Drop Ear Elbow	1/2 × 3/4 FPT	10	2.11	250
QADE44F	Drop Ear Elbow	3/4 × 3/4 FPT	10	2.80	250



CONTRACT NO. DACA05-83-C-0033
SUBMITTAL NO. 81
ITEM NO. 15
200 Manufactured/Factory-Built
Family Housing Units, FY-82
Fort Irwin, California

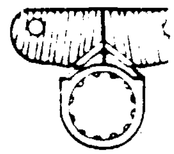
QEST PIPE CLAMI
AND STRAPPIN

PIPE CLAMP



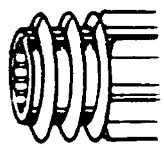
CAT. NO.	FOR NOM. TUBE SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QH1	1/4	100	08	1000
QH2	3/8	100	08	1000
QH3	1/2	100	09	1000
QH4	3/4	100	12	1000

INSULATED SUSPENSION CLAMP



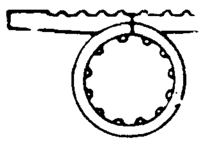
CAT. NO.	FOR NOM. TUBE SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QISC3	1/2	50	29	500
QISC4	3/4	50	34	500
QISC5	1	25	56	250

PIPE INSULATOR



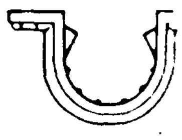
CAT. NO.	FOR NOM. TUBE SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QIS3	1/2	50	50	500
QIS4	3/4	50	50	500
QIS5	1	25	63	250

PIPE CLAMP



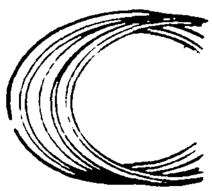
CAT. NO.	FOR NOM. TUBE SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QPC3	1/2	50	22	500
QPC4	3/4	50	.24	500
QPC5	1	25	36	250

HALF CLAMP



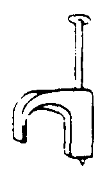
CAT. NO.	FOR NOM. TUBE SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QHC3	1/2	50	.14	500
QHC4	3/4	50	15	500

STRAPPING



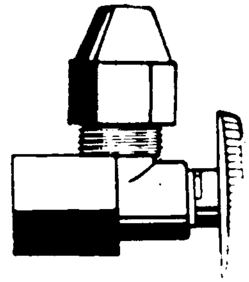
CAT. NO.	SIZE	COIL LENGTH FT.	LIST PRICE PER COIL	MASTER CARTON
QSTR4	3/4 wide	50	5.70	25

TUBE TALON



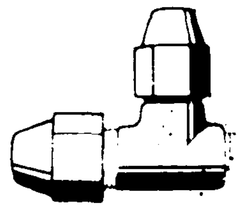
CAT. NO.	SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QTALON3	1/2 J. Hook Clamp (with nails)	100	082	1000
QTALON4	3/4 J. Hook Clamp (with nails)	100	105	1000

ANGLE STOP VALVES



FEMALE

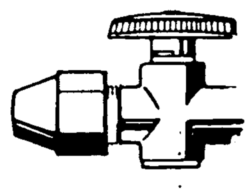
CAT. NO.	INLET × O.D. TUBE OUTLET	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QV352	3/8 FPT × 3/8 Compression	10	2.96	100
QV353	3/8 FPT × 1/2 Compression	10	2.96	100
QV302	1/2 FPT × 3/8 Compression	10	2.64	100
QV303	1/2 FPT × 1/2 Compression	10	2.62	100
QV301*	1/2 FPT × 1/2 MPT	10	2.37	100



QICKTITE

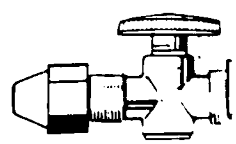
CAT. NO.	NOMINAL TUBE INLET × O.D. TUBE OUTLET	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QV332	3/8 Qicktite × 3/8 Compression	10	2.88	100
QV333	3/8 Qicktite × 1/2 Compression	10	2.88	100
QV342	1/2 Qicktite × 3/8 Compression	10	3.02	100
QV343	1/2 Qicktite × 1/2 Compression	10	3.02	100
QV341*	1/2 Qicktite × 1/2 MPT	10	2.46	100
QV311*	1/2 MPT × 1/2 MPT	10	2.20	100

STRAIGHT STOP VALVES



FEMALE

CAT. NO.	INLET × O.D. TUBE OUTLET	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QV452	3/8 FPT × 3/8 Compression	10	3.27	100
QV453	3/8 FPT × 1/2 Compression	10	3.27	100
QV402	1/2 FPT × 3/8 Compression	10	3.30	100
QV403	1/2 FPT × 1/2 Compression	10	3.30	100
QV401*	1/2 FPT × 1/2 MPT	10	2.71	100



QICKTITE

CAT. NO.	NOMINAL TUBE INLET × O.D. TUBE OUTLET	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QV432	3/8 Qicktite × 3/8 Compression	10	3.54	100
QV433	3/8 Qicktite × 1/2 Compression	10	3.54	100
QV442	1/2 Qicktite × 3/8 Compression	10	3.74	100
QV443	1/2 Qicktite × 1/2 Compression	10	3.74	100
QV411*	1/2 MPT × 1/2 MPT	10	2.50	100
QV421*	3/4 MPT × 1/2 MPT	10	2.55	100

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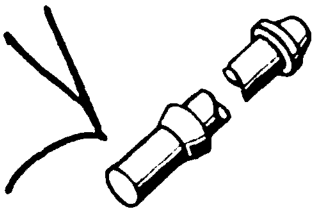
*To be used with riser assemblies. See page 35

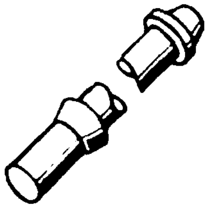
QEST SUPPLY TUBES



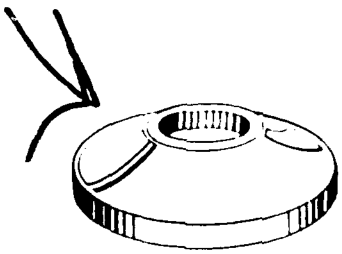
LAVATORY

BULK PACK

CAT. NO.	O.D. × LENGTH	LIST PRICE EACH
QBA12	3/8 × 12	435
QBA15	3/8 × 15	481
QBA20	3/8 × 20	556
QBA30	3/8 × 30	708
QBA36	3/8 × 36	990
QBA125	1/2 × 12	590
QBA155	1/2 × 15	670
QBA205	1/2 × 20	770
QBA305	1/2 × 30	1 050
QBA365	1/2 × 36	1 260



NOTE: Ferrule must be installed with small, tapered end fitting into stop valve (as pictured).



WALL PLATE (MOLDED GRAY POLYBUTYLENE)

ESCUTCHEON

CAT. NO.	DESCRIPTION	BAG QTY.	LIST PRICE EACH
QES120P	For Threaded 3/8 Nipple	100	.17
QES122P	For Threaded 1/2 Nipple	100	.17
QES128P	For 1/2 Nom. Copper	100	.17
QES130P	For 3/4 Nom. Copper	100	.17

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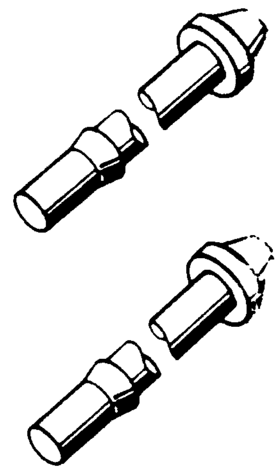
QEST SUPPLY TUBES

CLOSET

BULK PACK



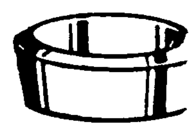
CAT. NO.	O.D. × LENGTH	LIST PRICE EACH	MASTER CARTON
QCL12	3/8 × 12	.435	100
QCL15	3/8 × 15	481	100
QCL20	3/8 × 20	556	100
QCL125	1/2 × 12	.590	100
QCL155	1/2 × 15	670	100
QCL205	1/2 × 20	.790	100

NOTE: Ferrule must be installed with small, tapered end fitting into stop valve (as pictured)

SEE NOTE

FERRULE

EXTRA COMPRESSION RINGS FOR SUPPLY TUBES

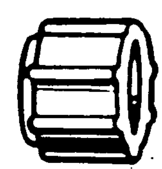


CAT. NO.	DESCRIPTION-SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QBF0	3/8 OD	100	080	1000
QBF1	1/2 OD	100	.068	1000
QBF2	5/8 OD	100	.161	1000

NOTE: Ferrule must be installed with small, tapered end fitting into stop valve (as pictured).

SEE NOTE

BALLCOCK NUT



CAT. NO.	THREAD SIZE	BAG QTY.	LIST PRICE EACH	MASTER CARTON
QBC4	Ballcock Nut Fits both 3/8 & 1/2 O.D. Supply Tubes	100	28	1000

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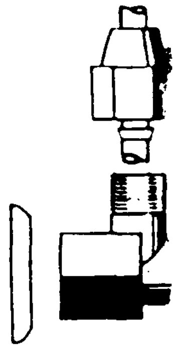
ANGLE CLOSET SUPPLIES

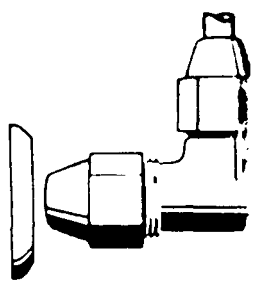
KIT INCLUDES:
- SUPPLY TUBE
- VALVE
- ESCUTCHEON

FEMALE



CAT. NO.	INLET	RISER O.D. LENGTH	BOX QTY.	LIST PRICE EACH	MASTER CARTON
QV352X12C	3/8 FIP	3/8 × 12	1	4.80	50
QV302X12C	1/2 FIP	3/8 × 12	1	4.40	50
QV302X15C	1/2 FIP	3/8 × 15	1	4.45	50
QV302X20C	1/2 FIP	3/8 × 20	1	4.60	50
QV303X12C	1/2 FIP	1/2 × 12	1	4.65	50
QV303X15C	1/2 FIP	1/2 × 15	1	4.70	50
QV303X20C	1/2 FIP	1/2 × 20	1	4.85	50

QICKTITE



CAT. NO.	NOMINAL INLET	RISER O.D. LENGTH	BOX QTY.	LIST PRICE EACH	MASTER CARTON
QV342X12C	1/2 Qicktite	3/8 × 12	1	4.50	50
QV342X15C	1/2 Qicktite	3/8 × 15	1	4.55	50
QV342X20C	1/2 Qicktite	3/8 × 20	1	4.70	50
QV343X12C	1/2 Qicktite	1/2 × 12	1	4.75	50

CONTRACT NO. DACA05-83-C-0033
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Fort Irwin, California

APPENDIX D
Product Specification Literature for Celon

Hoechst Celanese

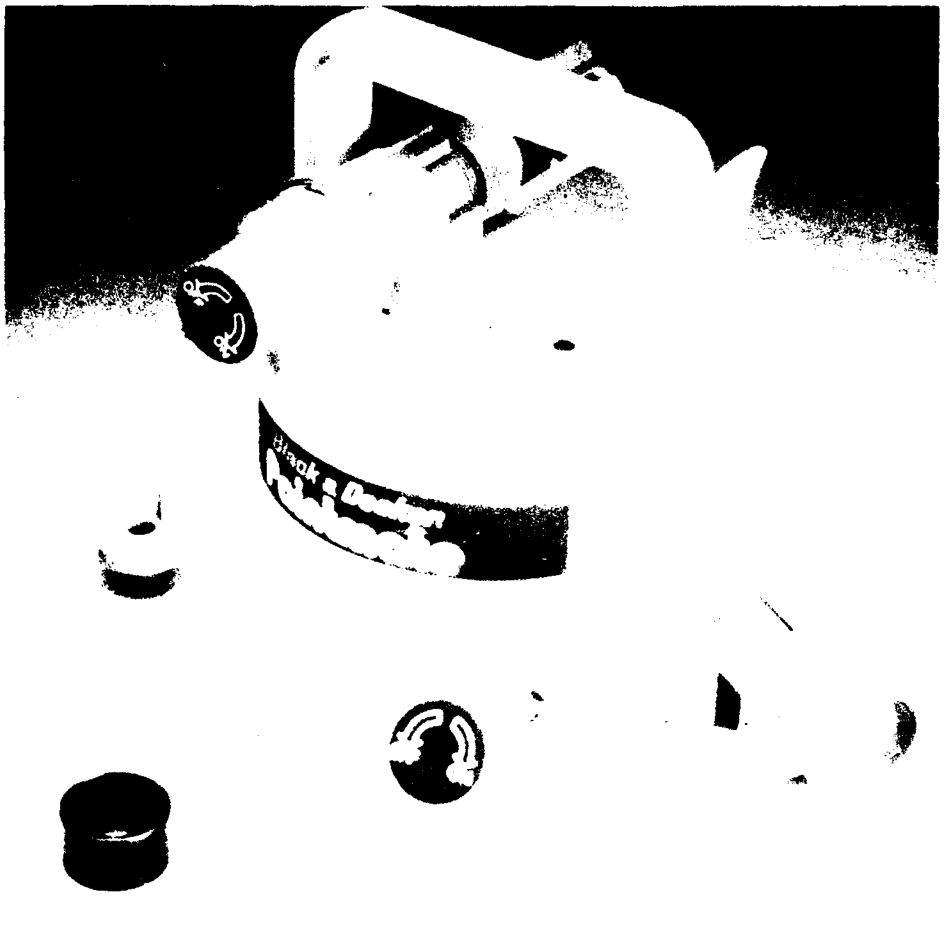
Celcon®

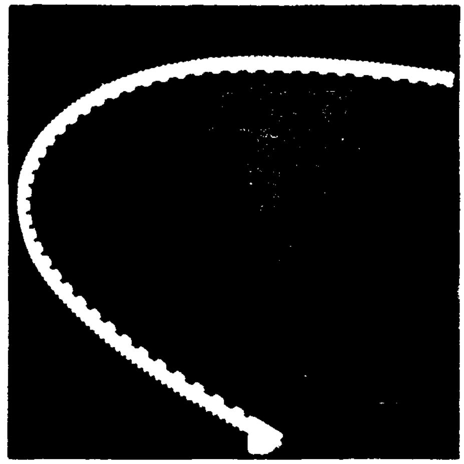
Acetal Copolymer

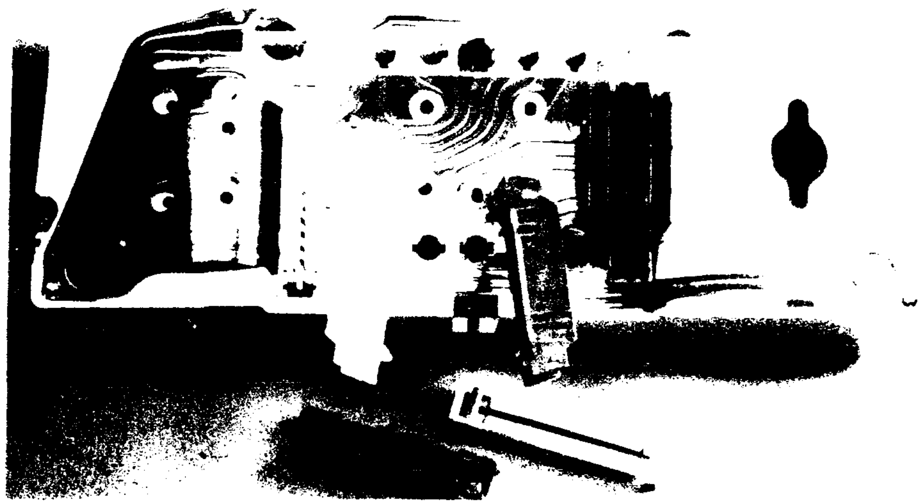
Properties CE-1A

Hoechst

CELCON ACETAL COPOLYMER
VERSATILITY IN DESIGN







Celcon® is the registered trademark of Hoechst Celanese Engineering Plastics Division used for its acetal copolymer. Celcon acetal copolymer is a high strength, crystalline, thermoplastic engineering resin whose unique balance of properties and ease of processibility offer performance and cost advantages over many other materials.

Celcon is widely accepted by engineers to design parts where thermosets, laminates, wood, die-cast and stamped metals such as magnesium, zinc, brass, iron and steel were formerly used. The superior performance of Celcon results from its high mechanical strength, stiffness, toughness, practical impact strength and, most importantly, its ability to maintain these properties over a broad range of temperatures and environments.

In addition to the versatility of design which Celcon offers engineers, it can also be processed by many conventional means including injection molding, blow molding, extrusion and rotational casting. Rod and slab stock from Celcon can also be easily machined.

Because of its unique properties and its ease of processing Celcon is used in an extraordinarily wide range of applications in a variety of end uses. Some of these applications, shown on the following pages, take advantage of the following physical and mechanical properties of Celcon, as well as the predictability of these characteristics over the long term. This predictability has been a major factor in the widespread acceptance of Celcon.

- high tensile strength and stiffness
- exceptional dynamic fatigue strength and dimensional stability
- practical toughness and resilience
- minimal moisture absorption
- low friction and wear properties making it one of the few natural bearing materials
- hard, high gloss surface
- superior property retention under extended exposure at temperatures up to 220°F in air and 180°F in water.
- exceptional resistance to a wide range of chemicals, oils, greases and solvents
- easy to process and fabricate

In addition, Celcon is available in a wide range of melt flows, specialty grades and colors to match numerous functional requirements.

Further contributing to the broad acceptance of Celcon are numerous agency code approvals. Although not a complete listing, end use approvals and/or specifications have been obtained for various Celcon grades from ASTM, FDA, NSF, UL, as well as plumbing code bodies such as IAPMO and BOCA. A detailed listing can be found on page 30.

Users of Celcon get more than a superior material; they are backed by the expertise of Hoechst Celanese Engineering Plastics Division, one of the leaders in engineering plastics.

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Values shown are based on testing of laboratory test specimens and represent data that falls within the normal range of properties for natural material. Colorants or other additives may cause significant variations in data values. These values are not intended for use in establishing maximum, minimum, or ranges of values for specification purposes. Any determination of the suitability of the material for any use contemplated by the user and the manner of such use is the sole responsibility of the user, who must assure himself that the material as subsequently processed meets the needs of his particular product or use.

AVAILABLE GRADES

STANDARD GRADES

Celcon acetal copolymer is available in a variety of unmodified grades in a range of melt indexes (1.0 to 45.0) to meet a wide variety of processing and design requirements. The standard acetal copolymers are designated as the "M" series while a high melt strength terpolymer is designated by a "U".

These letter designations are then followed by a 2 or 3 digit number which represents that grade's nominal melt index (melt viscosity) range.

All standard grades of Celcon acetal copolymer are translucent white. To meet other color requirements M90 and M270 are available in a wide range of pre-compounded colors. For special requirements custom matched colors can also be supplied for all grades. Processors who prefer to color compound in-plant can select from a wide range of color concentrates which can offer significant cost savings and production flexibility.

SPECIALTY GRADES

In addition to the standard grades described above, many specialty grades have been developed to meet the specific requirements of various demanding end-use applications. Among these are products whose properties provide improved stiffness, low-wear, high impact, ultra violet and weathering resistance, as well as anti-static and electroplating capability.

The addition of modifying agents to standard unfilled Celcon acetal copolymer grades to enhance one or more properties has an influence on all properties. Typically fiber glass and mineral fillers increase the density of the resin from 1.41 g/cc for unfilled grades to 1.48 for MC90 and MC270 and 1.60 for MC270HM and GC25A. The bar graphs presented below show the effect of modifiers on selected properties of Celcon acetal copolymers.

Detailed product information sheets are available for the specialty grades. New specialty grades are being developed constantly. Contact your Hoechst Celanese Engineering Plastics Division representative or local sales office for additional information on new grades.

FIGURE 1
TENSILE STRENGTH VS. GRADE

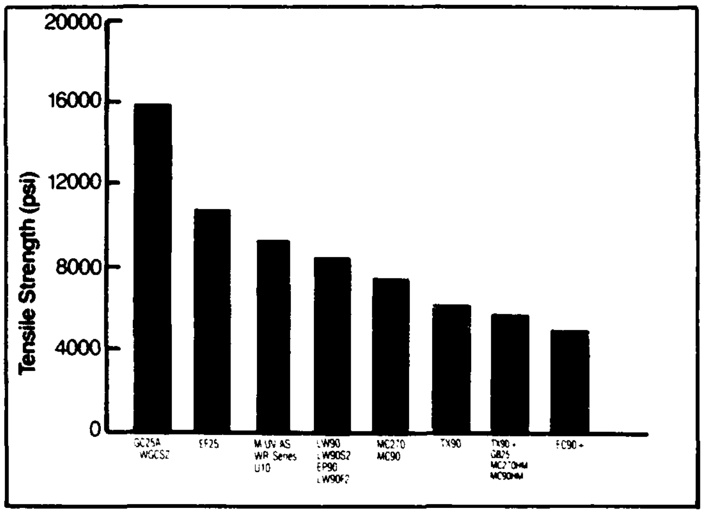


FIGURE 2
TENSILE ELONGATION VS. GRADE

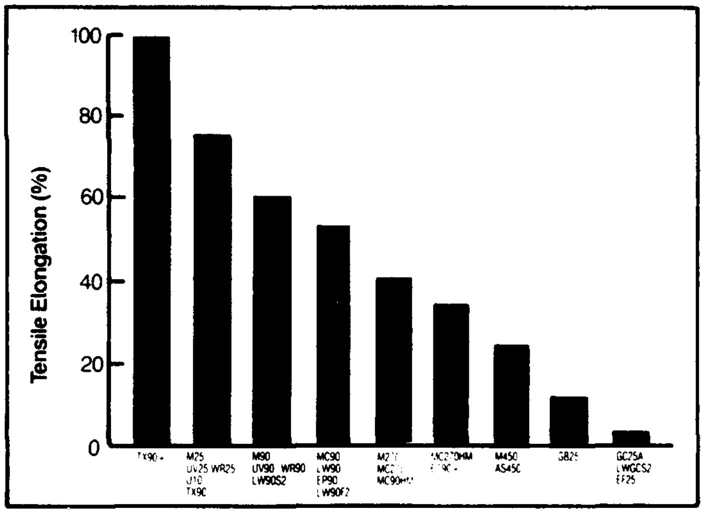


FIGURE 3
FLEXURAL MODULUS VS. GRADE

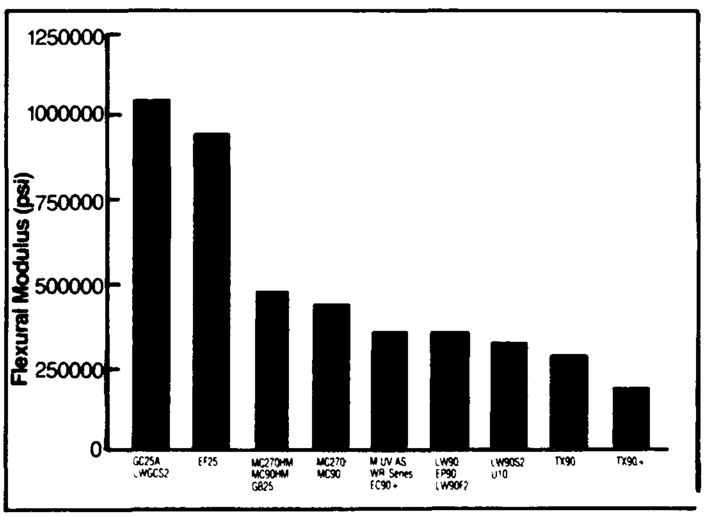


FIGURE 4
NOTCHED IZOD VS. GRADE

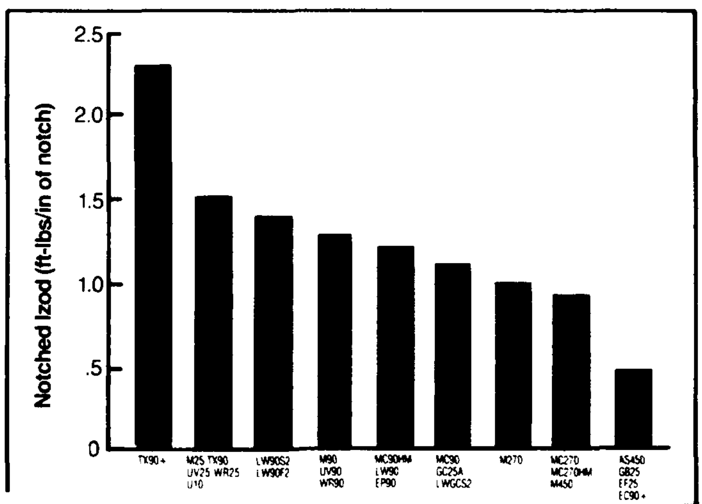


TABLE 1
STANDARD CELCON GRADES

Series	Melt Index	Description	Typical Applications
U10	1.0	A terpolymer with excellent melt strength and processibility in extrusion, blow molding and compression molding.	Aerosol containers, industrial tanks and floats, rod, tube, slab and profiles.
M25	2.5	High molecular weight grade primarily used for extrusion and selected injection molding applications in easy-to-fill molds.	Wire coatings, rod, tube, sheet and slab as well as injection molded items requiring extra toughness and elongation such as chain links, plumbing fittings and ski bindings.
M50	5.0	An extrusion and injection molding grade with an intermediate molecular weight tailored for selected applications in extrusion and injection molding.	Extruded rod, tube and slab as well as selected molded items requiring additional toughness.
M90	9.0	A general purpose injection molding grade with a molecular weight designed for excellent moldability and optimum properties in demanding applications.	A wide range of injection molded items where toughness and dimensional tolerances are important such as cams, gears, springs, knobs, check valves and drapery supports.
M140	14.0	A general purpose injection molding grade with slightly higher flow for use in hard-to-fill molds.	Injection molded items with less critical demands on toughness and dimensional tolerance.
M270	27.0	A lower molecular weight, high-flow grade designed for superior moldability in multi-cavity, intricate or hard-to-fill mold applications.	Parts molded on short cycle times which are less demanding on toughness than for an M90 material. Ideal for thin wall parts or long flow paths such as combs, marking pen bodies and housings.
M450	45.0	An extra high flow grade with reduced toughness designed for optimal cycle performance.	Dimensionally stable thin walled, low-load bearing parts such as audio/video tape hubs and micro gears.

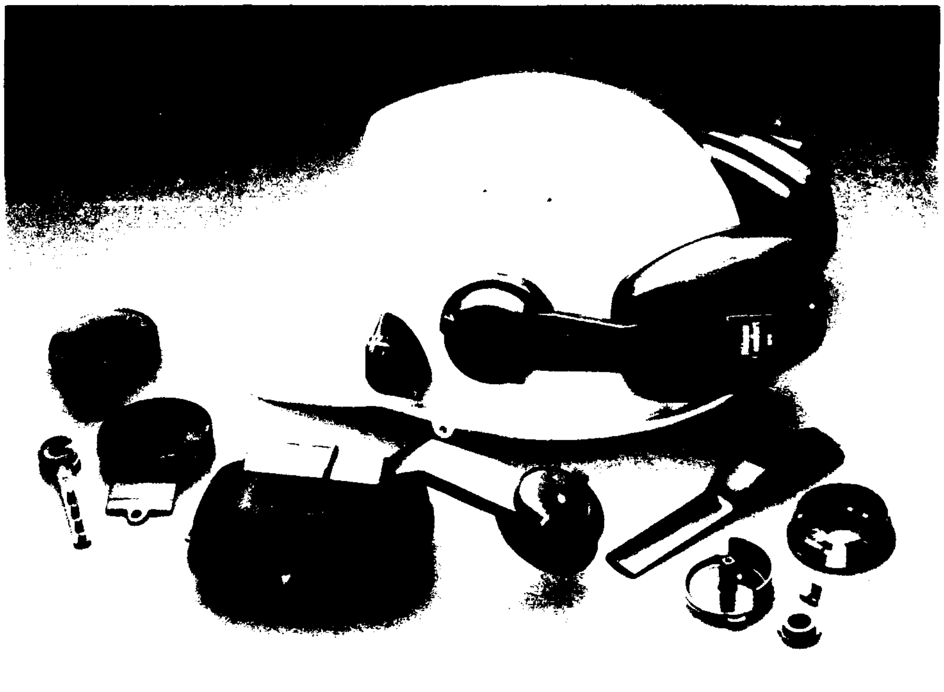
TABLE 2
SPECIALTY CELCON GRADES

Special Property	Product	Description	Application
U V Stabilized	UV90 UV25	Stabilized for use where U.V. degradation is a problem. Available in natural and custom matched colors.	Automotive interiors, and recreational items where exposure to sunlight causes discoloration and property loss, i.e., knobs, buttons, toys, cams and levers.
Weather Resistant	WR90 Black WR25 Black	Stabilized for use where maximum U.V. and outdoor weathering resistance is required.	Automotive, irrigation and recreational iter s.
Impact Modified	TX90 TX90 +	M90 grade modified for use where enhanced impact is required.	Automotive and industrial applications.
Glass Coupled	GC25A	A glass coupled formulation containing 25% fiber glass reinforcement. This grade offers an excellent balance of physical properties for applications requiring increased strength, stiffness, a reduced thermal expansion coefficient and increased heat distortion temperature. For specialized applications lower levels can be achieved by blending with M90.	Gears, machine housings, pressure vessels, valve bodies, marine hardware.
Low Wear	LW90 LW90S2 LWGCS2 LW90SC	This is an M90 grade formulated for high speed, low load wear applications against metal. The S2 suffix denotes a 2% silicone modification for use in low speed, high load applications. LWGC is 25% glass coupled grade. SC is a 20% silicone concentrate for use with all Celcon resins.	Bearings, slide plates, bushings, wear surfaces and conveyor links or plates.
Anti-Static	AS270 AS450	M270, M450 grades formulated to reduce static build-up on molded parts.	Audio or video cassette components, medical appliances and electrical items.
Mineral Coupled	MC90 MC90HM MC270 MC270HM	M90 and M270 grades formulated to provide increased stiffness, better dimensional stability and lower warpage. The HM suffix denotes highest modulus.	Gears, cams and gear pump covers where maximum stiffness and dimensional stability are required.
Electroplatable	EP90	An M90 grade designed to be electroplated using conventional electroless/electrolytic ABS processes.	High strength chrome plated parts to replace plated non-ferrous metals, i.e., faucets, automotive door knobs, window cranks, plumbing valves and appliance and consumer applications.
Glass bead	GB25	25% glass bead filled grade for low shrinkage and warp resistance in large flat and thin walled parts.	Cover and face plates where flatness is required.
Electroconductive	EC90 + EF25	A semi-conductive grade of acetal copolymer for applications requiring rapid dissipation of static build-up. A 25% carbon fiber reinforced acetal, reinforced for strength, stiffness and electrical conductivity.	Hospital operating room equipment and computer furniture where electrostatic build-up is not tolerable.

TYPICAL APPLICATIONS

Celcon has been specified by designers in a broad range of applications because of its cost performance and its ability to produce consistent, high quality parts under tight tolerances such as in the following markets:

INDUSTRIAL The widest range of applications for Celcon are found among industrial end users. These range from small gears and bearings to heavy duty conveyor links which are required to work under extremely arduous conditions, frequently without maintenance or lubrication. Dimensional stability, resilience and dynamic fatigue resistance to withstand repeated shock impact loads and abrasion resistance all contribute to long, trouble free performance.



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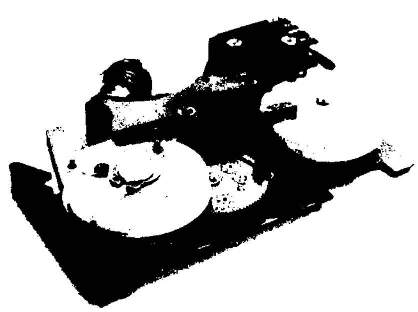
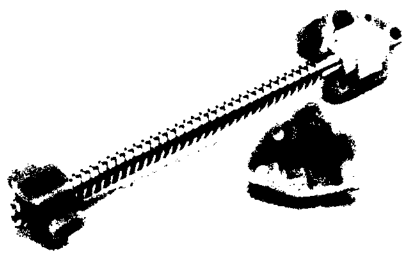
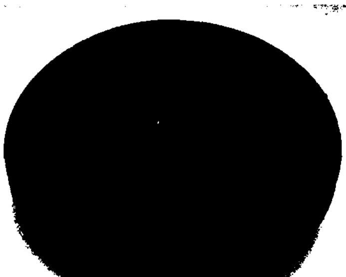


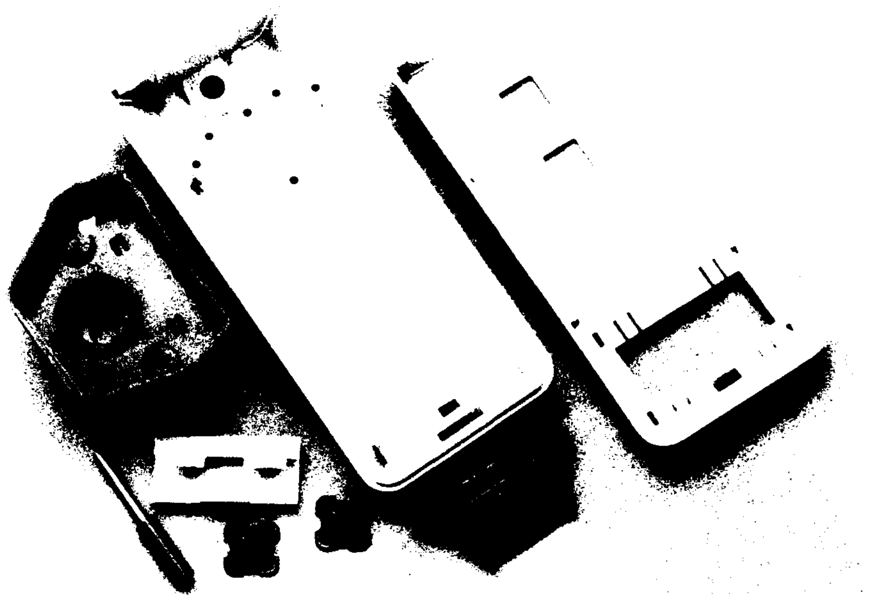
Timer gears



Worm gear



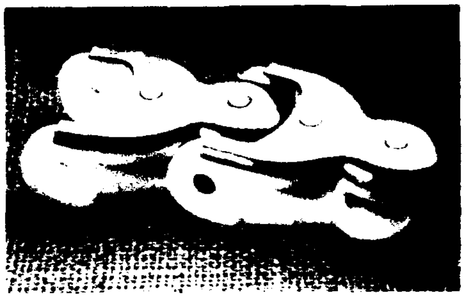
Seeder feed plate



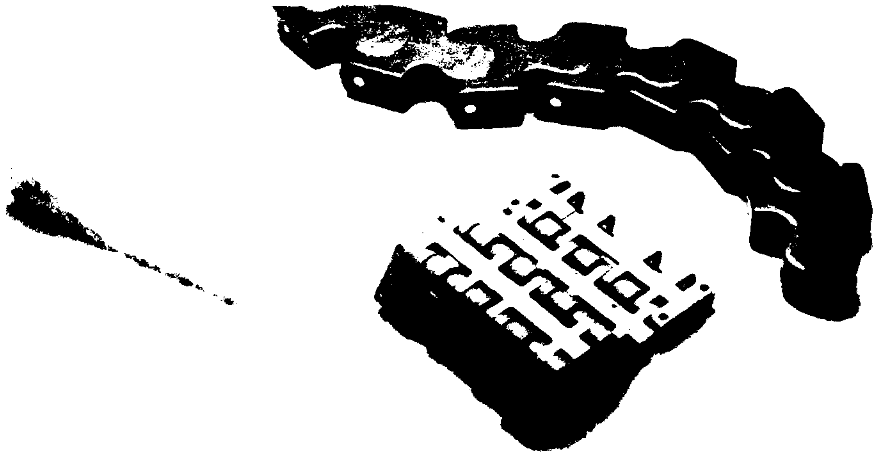
Digital tachometer

IATERIAL HANDLING equipment ıakes excellent use of the toughness, elf lubricity, impact and chemical esistance of Celcon acetal copolymer in arts such as conveyor chain links, slide earings, cams and bushings. In neumatic systems Celcon is used in alve bodies, hose connectors, pistons and wear stops.

Food and pharmaceutical production equipment applications in Celcon are widespread due to its chemical resistance and ability to withstand repeated short term steam sterilization. Many grades of Celcon are available that conform to FDA, USDA and NSF regulations.



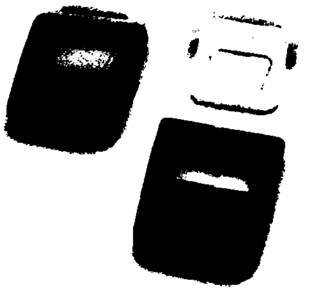
Conveyor links



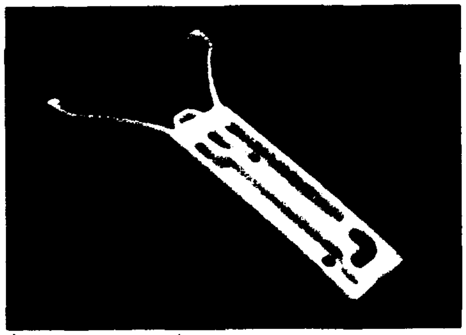
onveyor links

Waste removal flight pusher

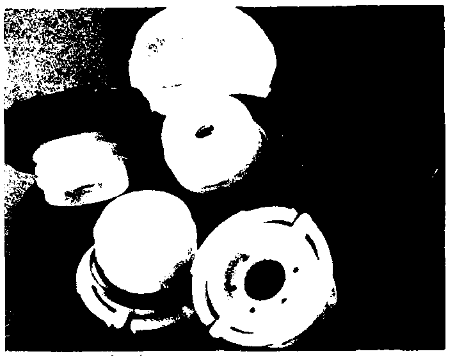
ı **AUTOMOTIVE** applications Celcon as *become the resin of choice for com*-onents of fuel and fuel-sending sys-əms—gas tank caps, fuel pumps and arburetor parts. In addition to fuel and oil əsistance, the high tensile strength and ɔng term dimensional stability of Celcon nder stress has made it the leading ıetal replacement for many other auto-ıotive parts including seat belt buckles, /indshield wiper components and win-low hardware.



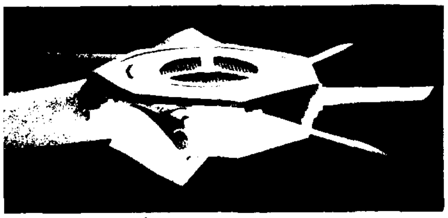
Safety belt buckles



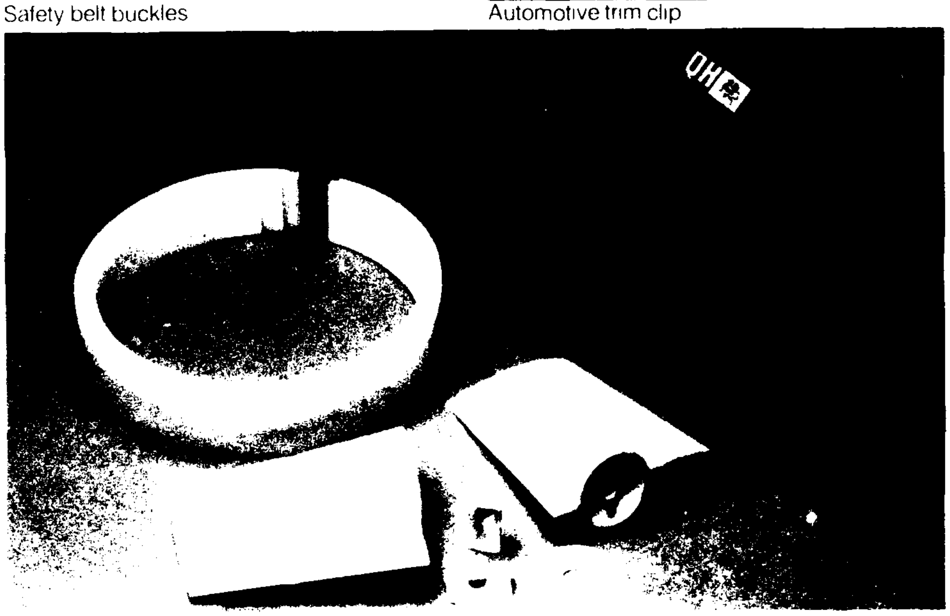
Automotive trim clip



ıutomotive fuel cap



ngine cooling fan



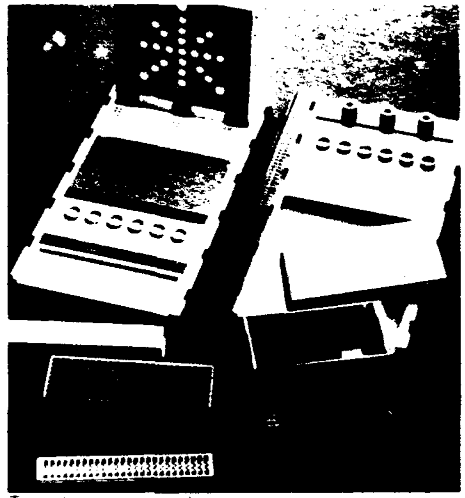
Engine cooling fan disassembled

TYPICAL APPLICATIONS

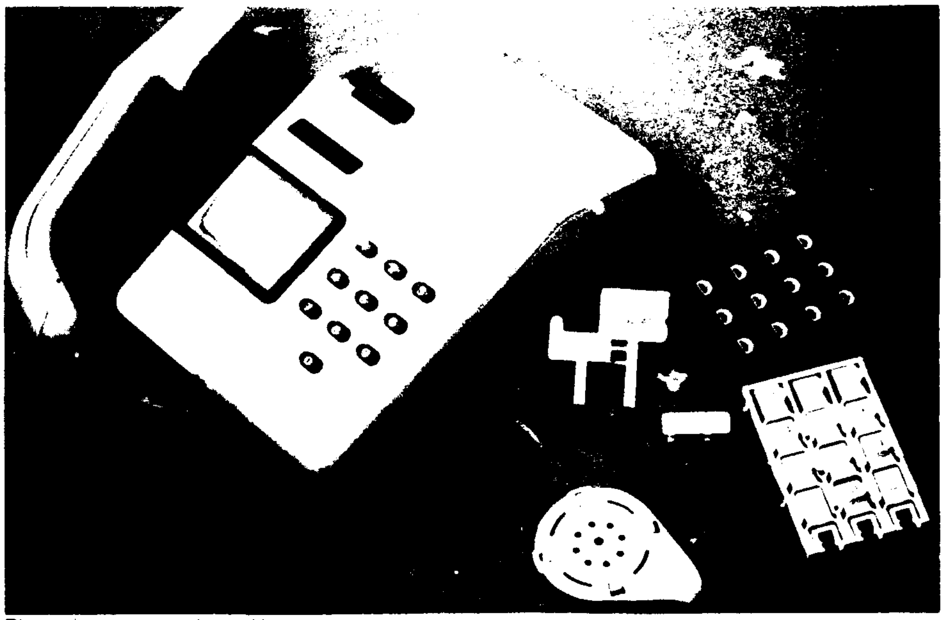
APPLIANCE components take advantage of the many unique properties of Celcon including stability over wide temperature ranges as well as resistance to soaps, detergents and animal fats. Typical applications include refrigerator clips and brackets, functional gears and bearings in washers and dryers; internal components of dishwashers such as spray nozzles, soap dispensers and rollers.

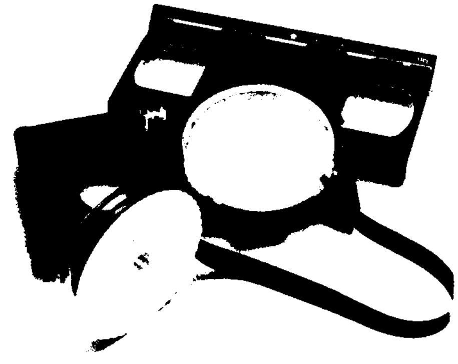
Celcon is used in various small appliances such as tea kettles, food processors and kitchen mixer bowls. Many of these applications take advantage of the ability of Celcon to resist staining, maintenance of a high gloss appearance and conformance to applicable FDA regulations for food contact.

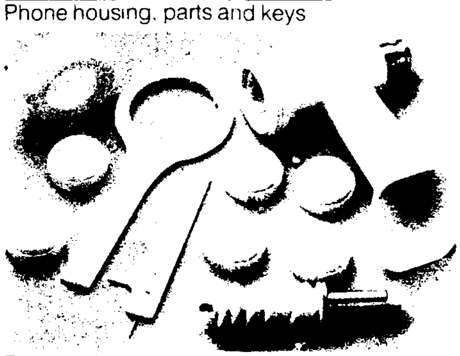
In **HOME ELECTRONICS,** Celcon is used extensively in the audio/video cassette industry for the production of bearings, reels, cams, gears, tape guides, rollers, and supply and take up reels. Celcon is the material of choice in these critical performance areas due to its inherent lubricity and low wear, dimensional stability, fatigue resistance and toughness. Celcon is also used in the production of electronic components through outsert molding which allows the manufacturer to simplify his design, eliminate assembly steps and reduce overall component costs.

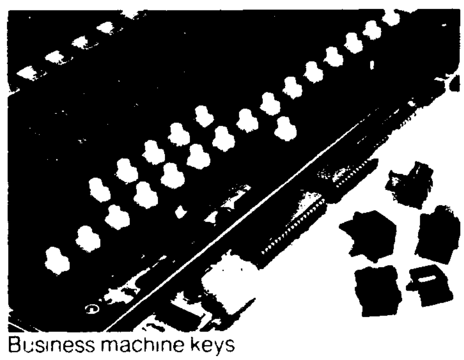

Test clips and peg boards


Food Processor Blades


Phone housing, parts and keys

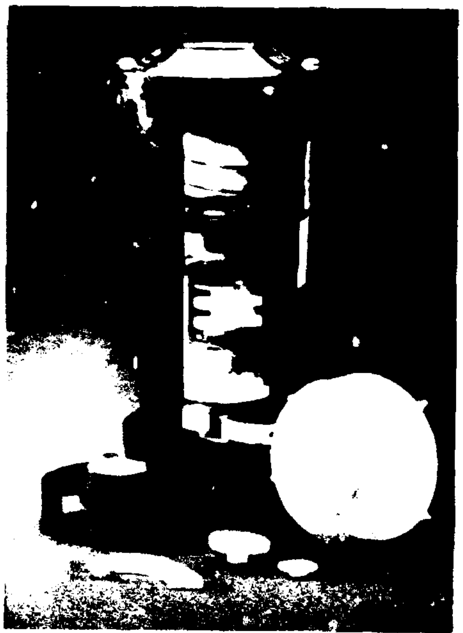

Video cassette reels


Pasta maker parts

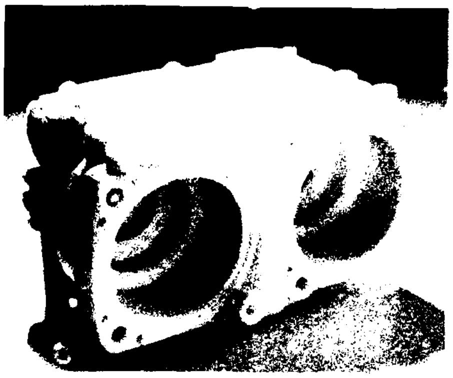

Business machine keys

elcon is used extensively in **PLUMBING** pplications due to its excellent retention f physical and mechanical properties llowing extended exposure in hot water nvironments. Aqueous solutions of reater than 1 ppm hypochlorite are not ecommended. Faucets molded entirely om Celcon have performed in a variety f domestic water environments without roblems for over 15 years. This application equires a material which can withstand particularly demanding environment, ncluding intermittent hot water exposure, esistance to continuous internal pressure, hread strength, torque retention and reep resistance while maintaining a igh gloss appearance for many years. Celcon also has excellent corrosion esistance, and its smooth, self lubricated urface resists the build up of scale making a faucet molded from Celcon virtually maintenance free.

In addition to these performance benefits Celcon costs less than brass on a cost per cubic inch basis and can be processed rapidly into parts by injection molding. Celcon plumbing grades have been approved for use with potable water by the National Sanitation Foundation and many comply with the regulations of the FDA as well. Applications for Celcon in the plumbing industry range from faucets to stop valves, ballcocks, ball valves, shower heads and fittings of all kinds and even to injection molded lavatory sinks, an application demonstrating the excellent high gloss appearance and hard durable surface which moldings of Celcon provide.



Pop-up irrigation sprinkler

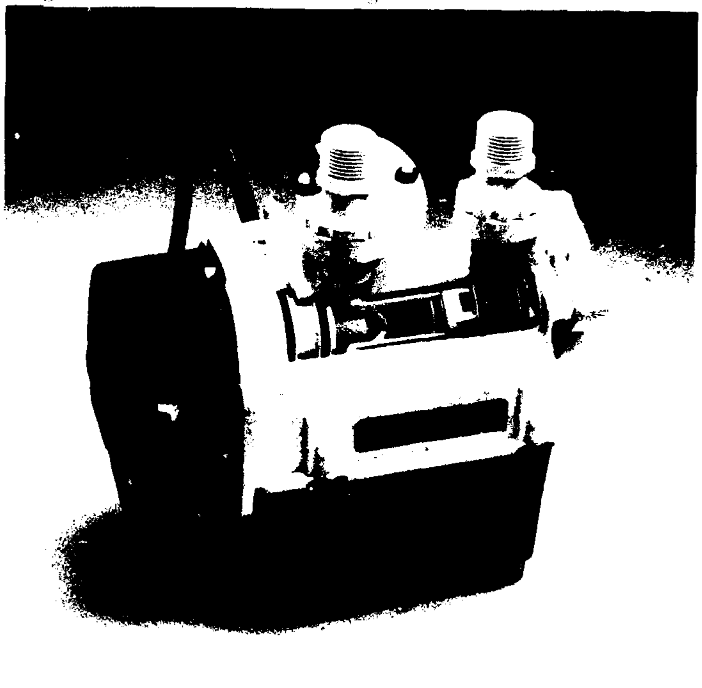


Vater softener housing

Water meter housing and gears

Filter housing

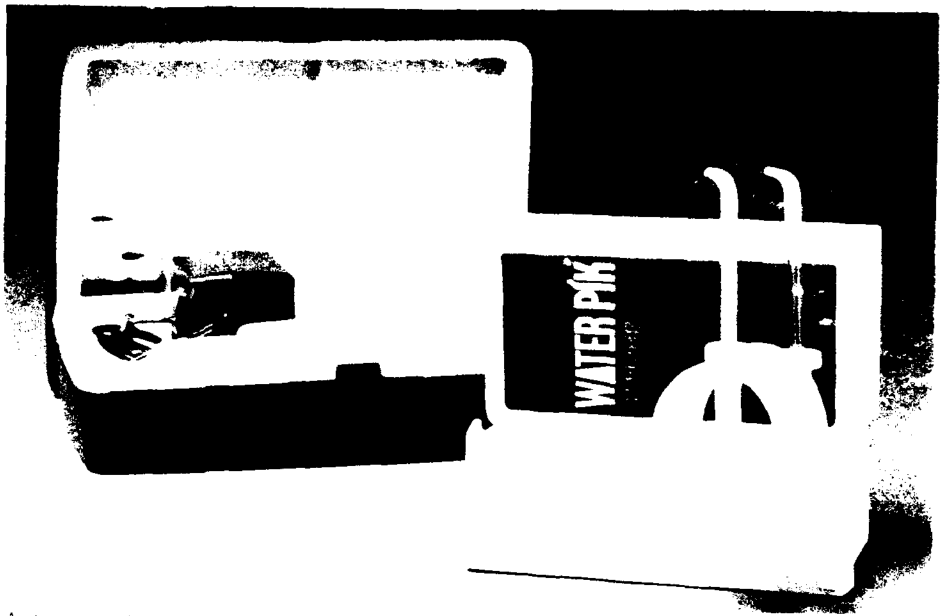
itchen faucet and under body components



Pump housing and internal components

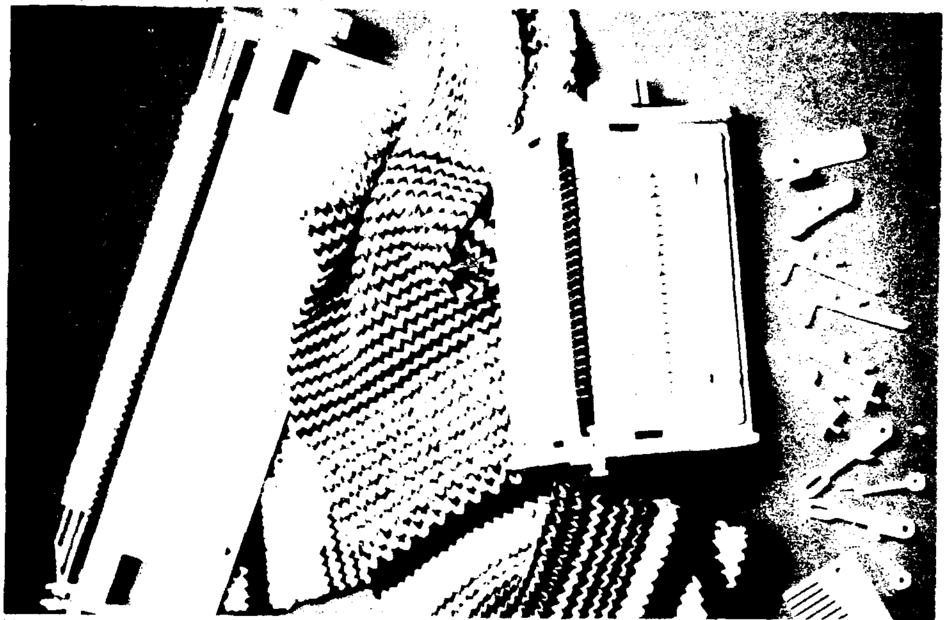
TYPICAL APPLICATIONS

CONSUMER APPLICATIONS show the versatility of Celcon in a wide variety of products such as electronic equipment, hardware and personal products where the performance benefits of Celcon have resulted in an extensive range of products to replace metals, reduce weight, improve appearance and durability as well as lower production costs. These products include zippers, cosmetic applicators and containers, aerosol valves, pen mechanisms and barrels, combs, cigarette lighter bodies and parts, watch cases, eye glass frames and the gears and mechanical parts for toys and cameras.



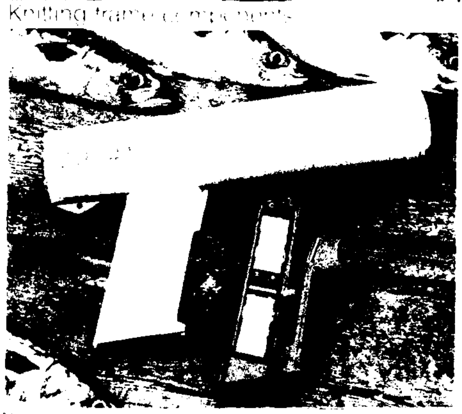
Water pik internal pump parts and cases

Power sprayer paint holder components



Knitting frame components

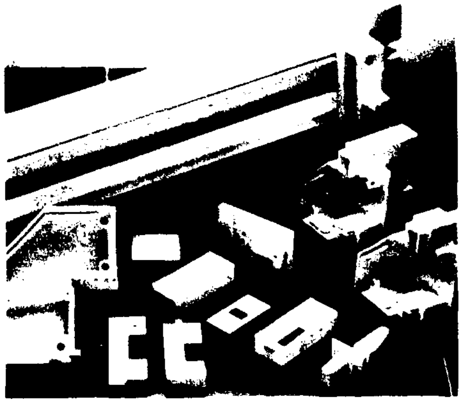
Paint spray gun and nozzle



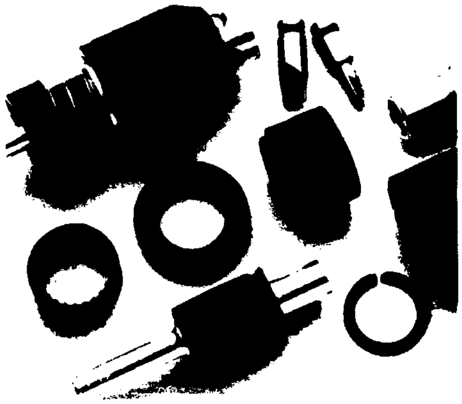
Battery holder for sonar fish finder

Cross-country ski binding

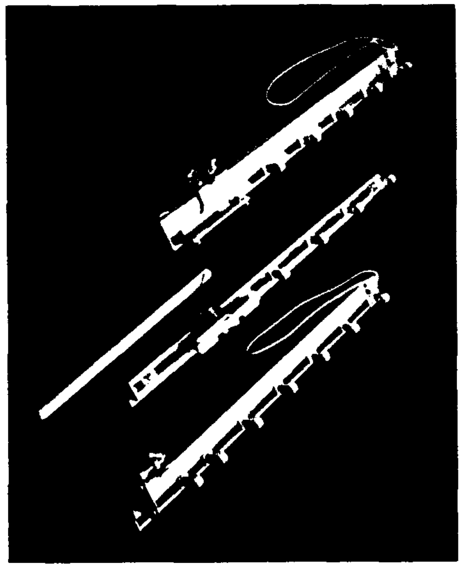
HARDWARE applications include drapery and venetian blind components, rollers, bearings and guides for office furniture and replacement of metal and rubber in the manufacture of furniture casters and wheels. These applications capitalize on the lubricity, light weight, colorability, platability and mechanical toughness of Celcon.



Window vent regulator

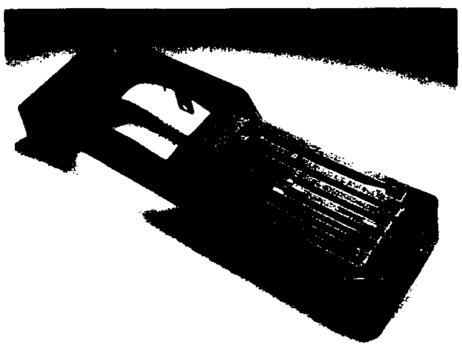


Drill screwdriver adapter



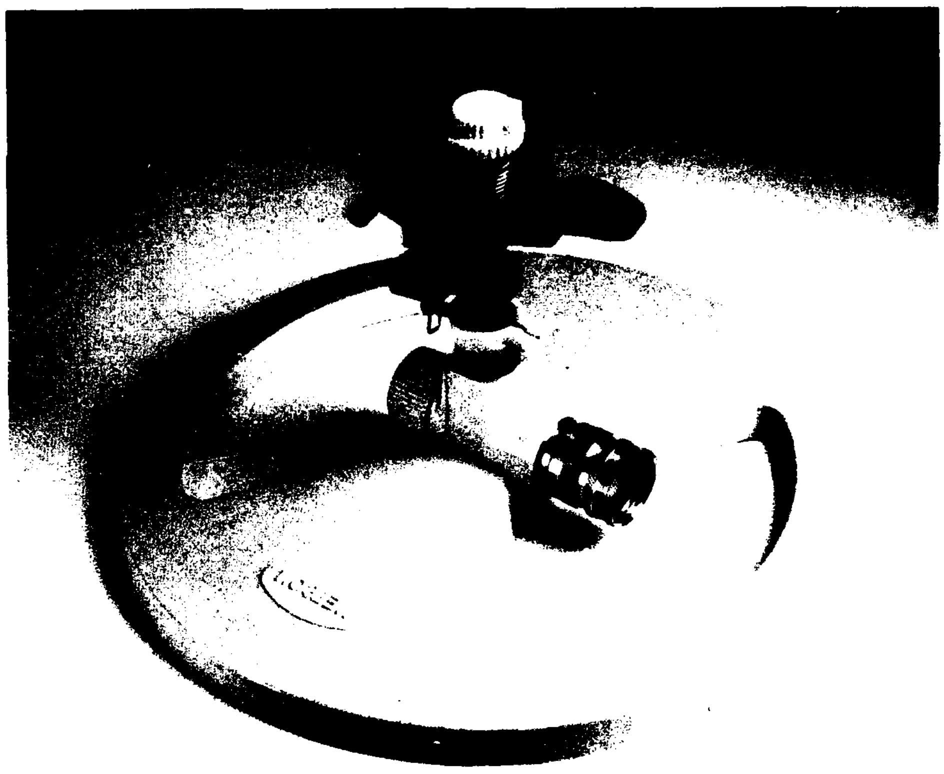
Drapery pull rods and hardware

AGRICULTURAL AND IRRIGATION APPLICATIONS require the chemical resistance, low wear, abrasion resistance and toughness of Celcon acetal copolymer in the design of equipment such as gear housings, bearings, water sprinklers, filters, spray heads, and metering valves.



Tractor gear shift housing

Tractor seed applicator cup housing



Lawn sprinkler parts

The information and property data in this bulletin were generated under laboratory conditions using ASTM test specimens. Processing and end-use conditions can affect part performance. It is essential that prototype parts made of Celcon® be tested under conditions expected in actual use.

SHORT TERM PROPERTIES

MECHANICAL

Physical properties determined by standard tests for the most widely used grades are listed in Table 3. These short-term properties show an exceptional balance of tensile properties, shear strength, stiffness, and toughness due to the unique resilience of Celcon acetal copolymer.

Celcon is one of the few natural bearing materials, exhibiting a very low coefficient of friction against metals, and excellent abrasion resistance.

The toughness of Celcon is evident in its combination of high tensile yield strength and the total area (a measure of work to failure) under its stress-strain curve (Figures 5-a, b, c).

A series of curves (Figures 6-10) show various effects of temperature and strain rate on tensile and flexural properties.

A combined tensile and compressive stress-strain curve appears in Figure 11.

TABLE 3
CELCON PROPERTIES—GENERAL SUMMARY

Property Physical and Mechanical	ASTM Test Method	Units	M450	M270	M90	M25
Specific Gravity, 23/23°C	D792	—	1,410	1,410	1,410	1,410
Density	—	lb./cu.in. (g/cm³)	0.0507 (1.41)	0.0507 (1.41)	0.0507 (1.41)	0.0507 (1.41)
Specific Volume	—	cu.in./lb. (cm³/g)	19.7 (0.709)	19.7 (0.709)	19.7 (0.709)	19.7 (0.709)
Tensile Strength at Yield	D638	psi (MPa)				
−40°F/−40°C	0.2"/min.		13,700 (94.5)	13,700 (94.5)	13,700 (94.5)	13,700 (94.5)
73°F/ 23°C			8,800 (60.7)	8,800 (60.7)	8,800 (60.7)	8,800 (60.7)
160°F/ 71°C			5,000 (34.5)	5,000 (34.5)	5,000 (34.5)	5,000 (34.5)
Elongation	D638	%				
−40°F/−40°C	0.2"/min.		10	15	20	30
73°F/ 23°C			25	40	60	75
160°F/ 71°C			>250	>250	>250	>250
Tensile Modulus	D638 0.2"/min.	psi (MPa)	410,000 (2,829)	410,000 (2,829)	410,000 (2,829)	410,000 (2,829)
Tensile Strength at Yield (High Speed - 10,000 in./min.)	Plastechon Universal Tester	psi (MPa)	11,000 (75.9)	11,000 (75.9)	11,000 (75.9)	11,000 (75.9)
Elongation	Plastechon Universal Tester	%	21	21	21	21
Flexural Stress at 5% Deformation	D790	psi (MPa)	13,000 (89.7)	13,000 (89.7)	13,000 (89.7)	13,000 (89.7)
Flexural Modulus	D790	psi (MPa)				
73°F/ 23°C			375,000 (2,588)	375,000 (2,588)	375,000 (2,588)	375,000 (2,588)
160°F/ 71°C			180,000 (1,242)	180,000 (1,242)	180,000 (1,242)	180,000 (1,242)
220°F/104°C			100,000 (690)	100,000 (690)	100,000 (690)	100,000 (690)
Fatigue Endurance Limit at 10^7 Cycles	D671	psi (MPa)	3,000 (20.7)	3,000 (20.7)	3,000 (22.8)	3,000 (27.6)
Compressive Stress	D695	psi				
at 1% Deflection			4,500 (31.0)	4,500 (31.0)	4,500 (31.0)	4,500 (31.0)
at 10% Deflection			16,000 (110.4)	16,000 (110.4)	16,000 (110.4)	16,000 (110.4)
Hardness, Rockwell	D785	—	M80	M80	M80	M78
Izod Impact Strength (notched)	D256	ft.lb./in. (J/m) of notch				
−40°F/−40°C			0.7 (37.4)	0.8 (42.7)	1.0 (53.4)	1.2 (64.0)
73°F/ 23°C			0.9 (48.1)	1.0 (53.4)	1.3 (69.4)	1.5 (80.0)
(unnotched)		ft.lb./in. (J/m)				
73°F/ 23°C			—	17 (907)	20 (1,067)	25 (1,334)
Tensile Impact Strength						
73°F/ 23°C	D1822	ft.lb./sq.in. (kJ/m²)	50 (105.5)	60 (126)	70 (147)	90 (189)
Water Absorption, 73°F/23°C	D570	%				
24 hr. Immersion			0.22	0.22	0.22	0.22
Equilibrium, 50% RH			0.16	0.16	0.16	0.16
Equilibrium, Continuous Immersion			0.80	0.80	0.80	0.80
Shear Strength	D732	psi (MPa)				
73°F/23°C			7,700 (53.1)	7,700 (53.1)	7,700 (53.1)	7,700 (53.1)
120°F/49°C			6,700 (46.2)	6,700 (46.2)	6,700 (46.2)	6,700 (46.2)
160°F/71°C			5,700 (39.3)	5,700 (39.3)	5,700 (39.3)	5,700 (39.3)
Taber Abrasion	D1044	mg/1,000 cycles				
1000 g. load, CS-17 wheel			14	14	14	14
1000 g. load, CS-17F wheel			6	6	6	6
Coefficient of Dynamic Friction against	D1894					
Steel			0.15	0.15	0.15	0.15
Brass			0.15	0.15	0.15	0.15
Aluminum	0.15	0.15	0.15	0.15		
Celcon			0.35	0.35	0.35	0.35

FIGURE 5A
ENERGY REQUIRED TO FAIL
(CELCON M25)

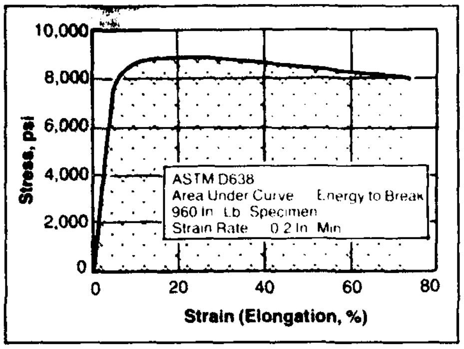


FIGURE 5B
ENERGY REQUIRED TO FAIL
(CELCON M90)

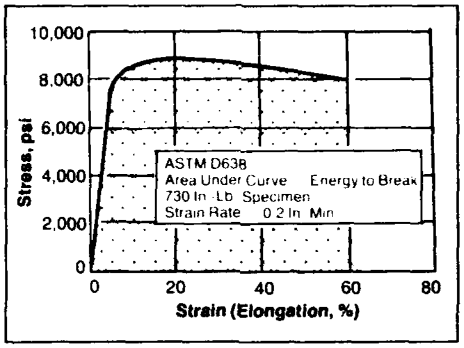


FIGURE 5C
ENERGY REQUIRED TO FAIL
(CELCON M270)

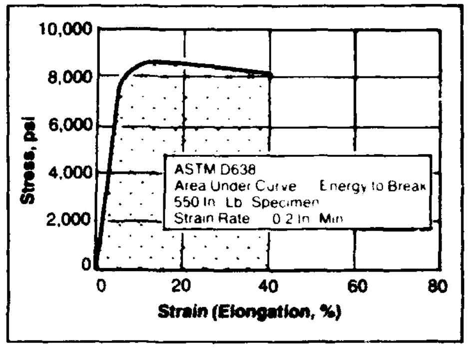


FIGURE 6
EFFECT OF AMBIENT TEMPERATURE ON ULTIMATE ELONGATION
(CELCON M90)

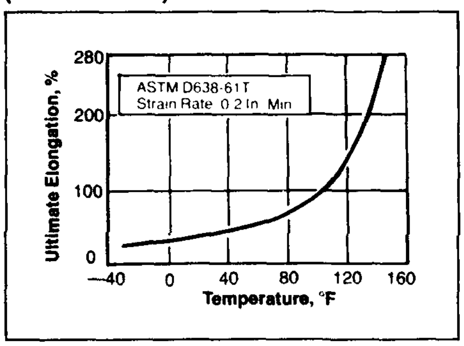


FIGURE 7
EFFECT OF AMBIENT TEMPERATURE ON TENSILE STRESS AT YIELD POINT
(CELCON M90)

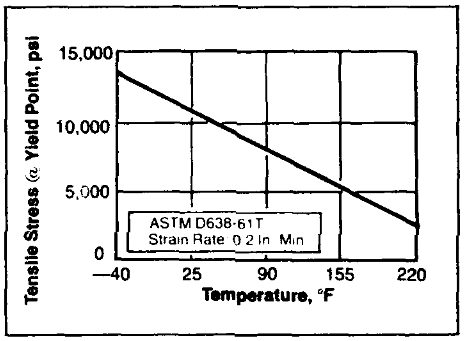


FIGURE 8
TENSILE MODULUS VS. TEMPERATURE
ASTM D-638-611
(0.2 IN./MIN.)

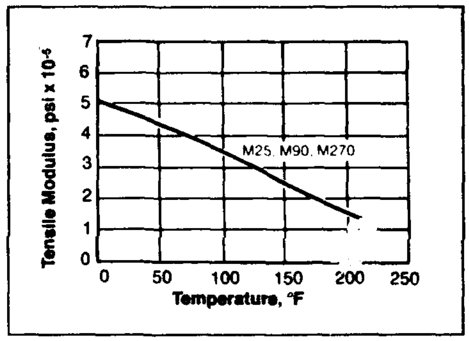


FIGURE 9
INFLUENCE OF STRAIN RATE ON TENSILE MODULUS

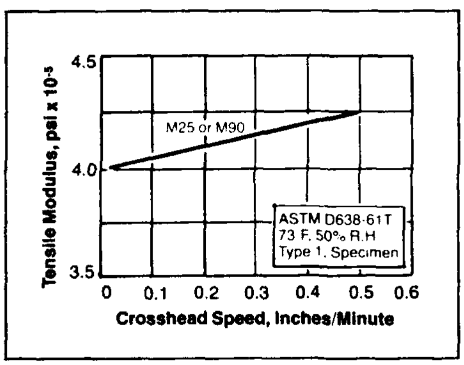


FIGURE 10
EFFECT OF AMBIENT TEMPERATURE ON FLEXURAL MODULUS
(STRAIN RATE 0.2 IN./MIN.)

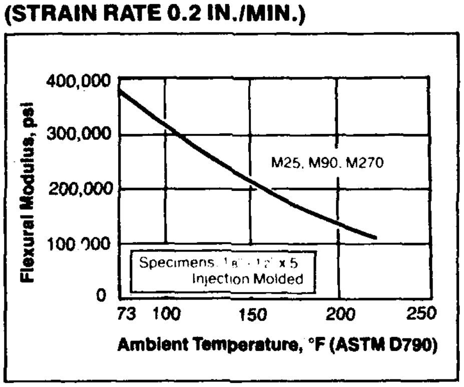
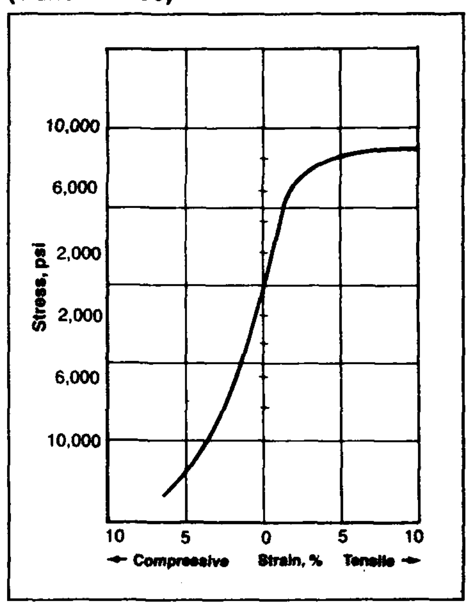


FIGURE 11
STRESS-STRAIN CURVE @ 73°F.
(CELCON M90)



Footnote to Table 3:
Many of the properties of thermoplastics are dependent upon processing conditions. The test results presented in Table 3 were obtained under standardized test conditions at 50% R.H. and 73°F unless indicated otherwise. Values were obtained from specimens injection molded in unpigmented material. In common with other thermoplastics, incorporation into Celcon of color pigments or additional U.V. stabilizers may affect some test results.

THERMAL PROPERTIES

Celcon acetal copolymer has unusually good thermal properties as shown (Table 4) in its deflection temperature, Vicat softening point and in the graphs shown in the Long-Term Properties section which follows. Linear thermal expansion is plotted in Figure 12.

Parts made of Celcon have excellent resistance to high intermittent temperatures since its sharp melt point characteristic means it retains its shape and physical integrity at elevated temperatures.

Long-term stability at high temperature is outstanding. Celcon samples show excellent retention of initial mechanical properties in hot air and hot water. Details appear with other Celcon plastic performance data in the Long-Term Properties section of this bulletin.

FIGURE 12
LINEAR THERMAL EXPANSION VS. TEMPERATURE (CELCON M90)

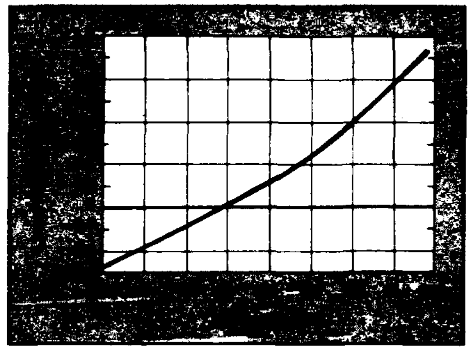
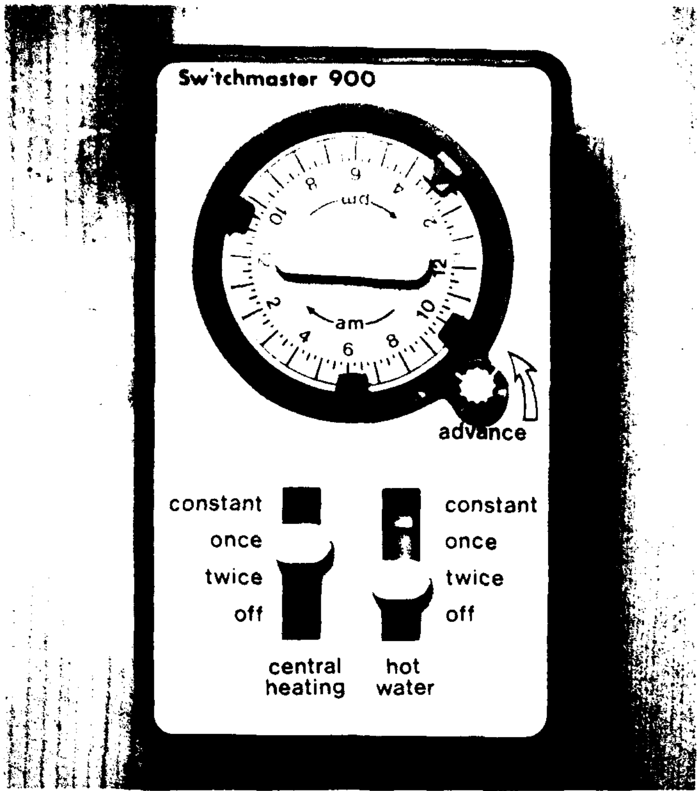


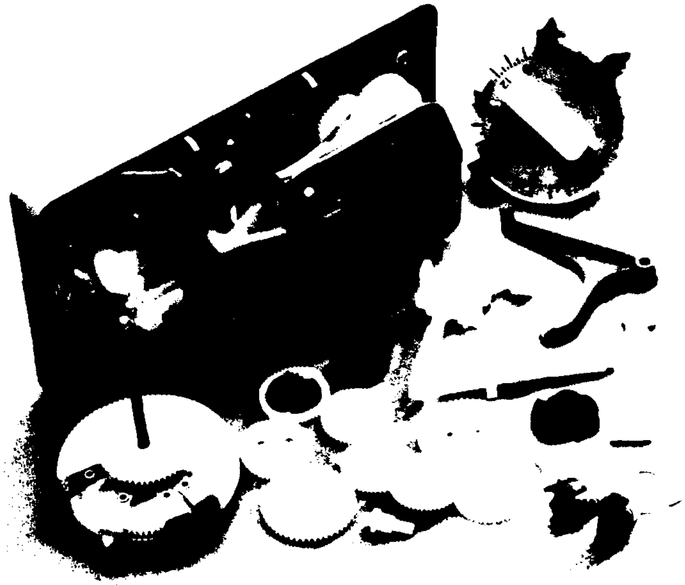
TABLE 4
THERMAL PROPERTIES

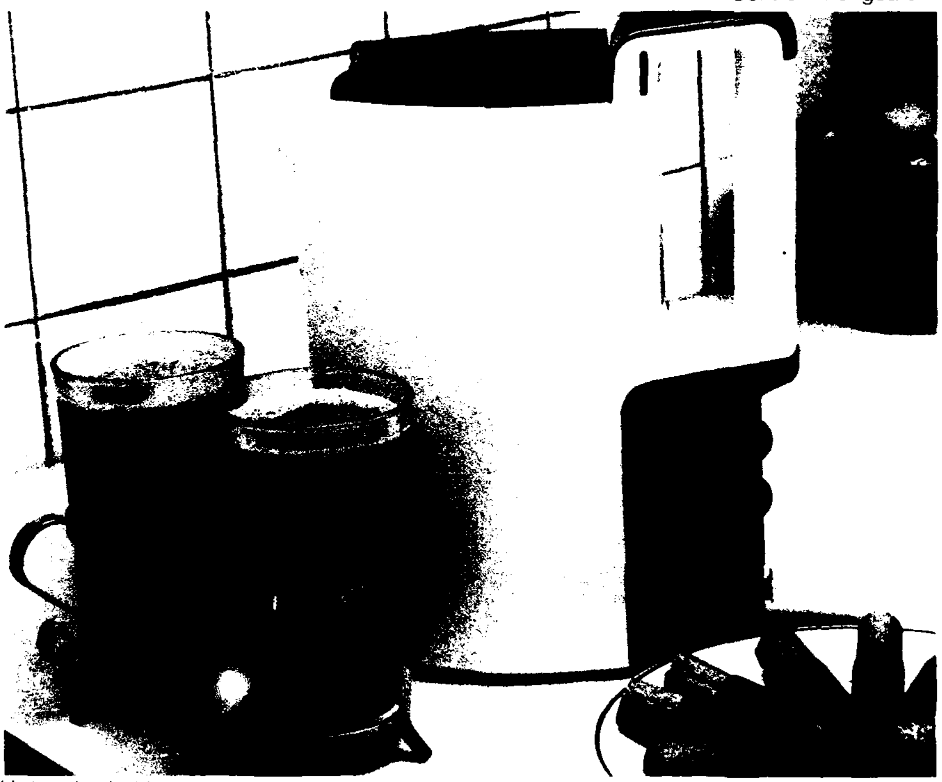
Property	ASTM Test Method	Units	M450	M270	M90	M25
Flow						
Flow Temperature	D569	°F (°C)	345 (174)	345 (174)	345 (174)	345 (174)
Melting Point		°F (°C)	329 (165)	329 (165)	329 (165)	329 (165)
Melt Index	D1238	g/10 min.	27.0	27.0	9.0	2.5
Vicat Softening Point	D1525	°F (C°)	324 (162)	324 (162)	324 (162)	324 (162)
Thermal Deflection and Deformation						
Deflection Temperature	D648					
@ 264 psi		°F (C°)	230 (110)	230 (110)	230 (110)	230 (110)
@ 66 psi		°F (C°)	316 (157)	316 (157)	316 (157)	316 (157)
Deformation under Load						
(2000 psi @ 122°F)	D621	%	1.0	1.0	1.0	1.0
Miscellaneous						
Thermal Conductivity	—	BTU/hr/ft^2/°F/in.	1.6 (0.00552)	1.6 (0.00552)	1.6 (0.00552)	1.6 (0.00552)
	—	(cal/sec/cm^2/°C/cm				
Specific Heat		BTU/lb/°F (cal/g/°C)	0.35 (0.35)	0.35 (0.35)	0.35 (0.35)	0.35 (0.35)
Coefficient of Linear Thermal Expansion	D696	in./in./°F (cm/cm/°C)				
(Range: −30°C to +30°C)						
Flow Direction			$4.7x10^{-5}$ ($8.5x10^{-5}$)	$4.7x10^{-5}$ ($8.5x10^{-5}$)	$4.7x10^{-5}$ ($8.5x10^{-5}$)	$4.7x10^{-5}$ ($8.5x10^{-5}$)
Transverse direction			$4.7x10^{-5}$ ($8.5x10^{-5}$)	$4.7x10^{-5}$ ($8.5x10^{-5}$)	$4.7x10^{-5}$ ($8.5x10^{-5}$)	$4.7x10^{-5}$ ($8.5x10^{-5}$)
Flammability (1)	D635	in./min. (mm/min.)	1.1 (2.8)	1.1 (2.8)	1.1 (2.8)	1.1 (2.8)
Underwriters Rating	—	—	HB	HB	HB	HB
Average Mold Shrinkage (2)	—	in./in. (cm/cm)				
Flow direction			0.022 (0.022)	0.022 (0.022)	0.022 (0.022)	0.022 (0.022)
Transverse direction			0.018 (0.018)	0.018 (0.018)	0.018 (0.018)	0.018 (0.018)

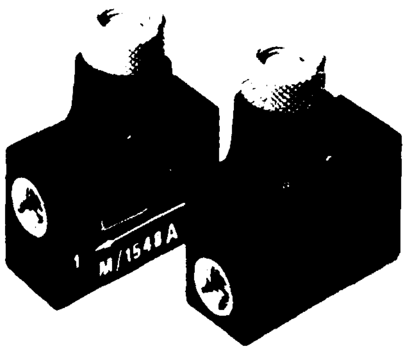
(1) UL94, down to 0.028".
(2) Data Bulletin C3A, "Injection Molding of Celcon" provides information and factors which influence mold shrinkage.



Control timer


Control timer gears


Hot water kettle



Air Flow Control Valves

PROPERTIES—SHORT-TERM

ELECTRICAL

Electrical properties of Celcon acetal copolymer as shown in Table 5 include good dielectric strength, good dissipation factor, low dielectric constant over a range of frequencies, high volume resistivity and excellent arc resistance. More importantly, Celcon combines these properties with exceptional mechanical strength and heat resistance. These combined properties, plus long-term stability, make Celcon useful in many varied electrical applications.

The dielectric constant and the loss tangent (equivalent to power factor at low values) have been measured on a Schering bridge in the frequency range from 30 Hz to 30,000 Hz and the temperature range from -112°F to 250°F on samples of M grade Celcon in air. Results appear in Figures 13 and 14.

Figure 14 shows that there are two main regions of high loss:

a. a low frequency, high temperature region which is due to a conduction process and
b. a loss hump at low temperature attributed to a dipolar relaxation mechanism.

These results show that there is a useful range of temperatures from -40°F to 120°F where losses are relatively low and the dielectric constant changes only slightly with temperature and frequency. At room temperature and 10^5 Hz and above there are maximum losses which preclude the use of Celcon acetal copolymer in some applications at high frequencies. Many grades of Celcon have been evaluated by Underwriter's Laboratories and Yellow Cards are available indicating their property profiles.

TABLE 5
ELECTRICAL PROPERTIES
(AT 73°F & 50% RH)

Property	ASTM Test Method	Units	M450	M270	M90	M25
Dielectric Constant (40 mil. sheet)	D150	—				
10^2 Hertz			3.7	3.7	3.7	3.7
10^3 Hertz			3.7	3.7	3.7	3.7
10^4 Hertz			3.7	3.7	3.7	3.7
10^6 Hertz			3.7	3.7	3.7	3.7
Dissipation (Power) Factor						
(40 mil. sheet)	D150	—				
10^2 Hertz			0.0010	0.0010	0.0010	0.0010
10^3 Hertz			0.0010	0.0010	0.0010	0.0010
10^4 Hertz			0.0015	0.0015	0.0015	0.0015
10^6 Hertz			0.006	0.006	0.006	0.006
Surface Resistivity (1/8" thick)	D257	ohm	$1.3x10^{16}$	$1.3x10^{16}$	$1.3x10^{16}$	$1.3x10^{16}$
Volume Resistivity (1/8" thick)	D257	ohm-cm	$1x10^{14}$	$1x10^{14}$	$1x10^{14}$	$1x10^{14}$
Arc Resistance (1/8" thick)	D495	seconds	240 (burns)	240 (burns)	240 (burns)	240 (burns)
Dielectric Strength	D149	volts/mil				
Short Time						
5 mil. film			2100	2100	2100	2100
90 mil. sheet			500	500	500	500
Loss Factor (40 mil sheet)	D150					
10^2 Hertz			0.005	0.005	0.005	0.005
10^3 Hertz			0.005	0.005	0.005	0.005
10^4 Hertz			0.005	0.005	0.005	0.005
10^6 Hertz			0.024	0.024	0.024	0.024

FIGURE 13
VARIATION OF DIELECTRIC CONSTANT WITH TEMPERATURE AND FREQUENCY

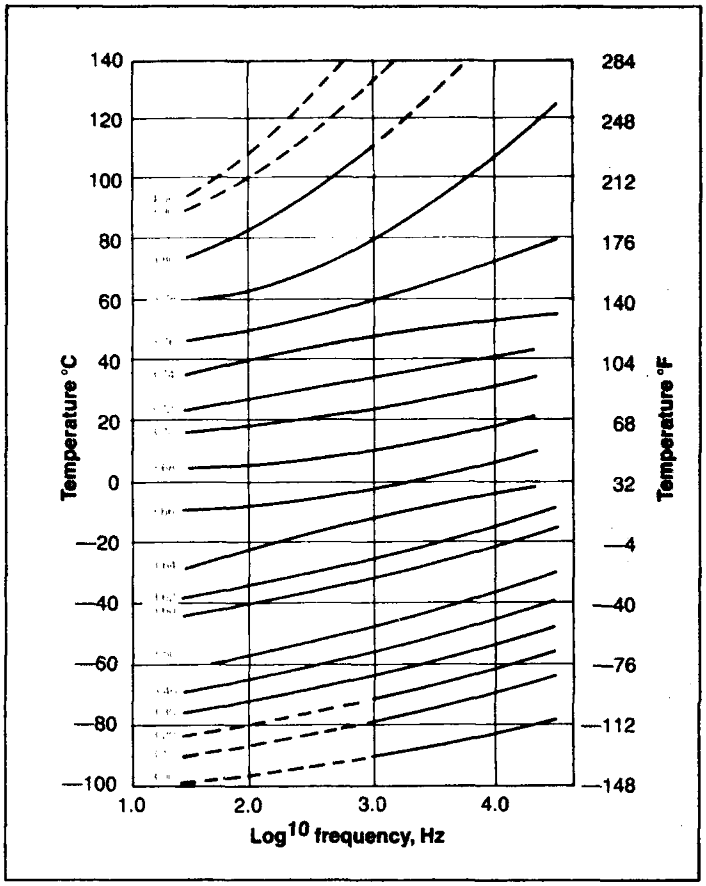
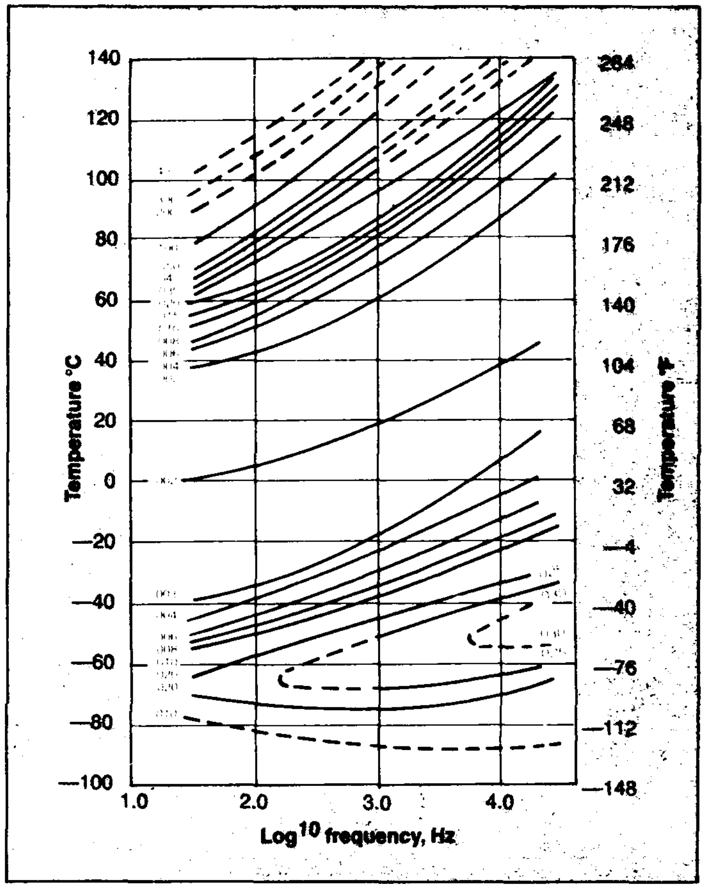
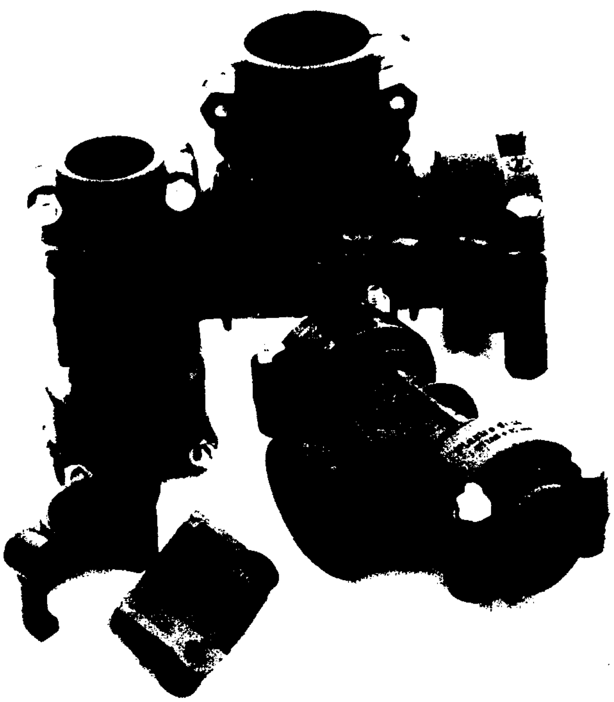


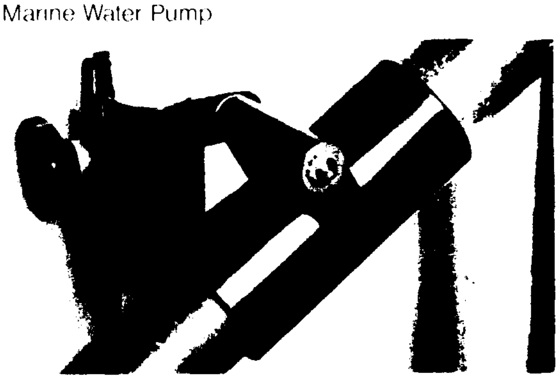
FIGURE 14
VARIATION OF DIELECTRIC LOSS TANGENT WITH TEMPERATURE AND FREQUENCY





Drip Irrigation Couplings

Marine Water Pump



Pivot Clamp and Guide

LONG-TERM PROPERTIES

Standard mechanical properties, which differentiate plastics on the basis of short-term tests, indicate material differences. They are useful in design engineering only when considered with long range effects. Most products made of engineering plastics are intended to give many years service. Long-term tests on Celcon acetal copolymer prove it truly outstanding in permanence and stability. The test results which follow show why.

ENVIRONMENTAL AGING—NO LOAD

To find how various environments—chemicals, heat, and weather—affect Celcon resins, numerous samples were placed in various environments and held continuously for a year or longer. Tests at intervals show how each environment affects the properties and physical characteristics of Celcon acetal copolymer. Some environments (strong mineral acids and oxidizing agents, for instance) are injurious

FIGURE 15
EFFECT OF HEAT AGING ON TENSILE STRENGTH FOR CELCON M90 AND M25

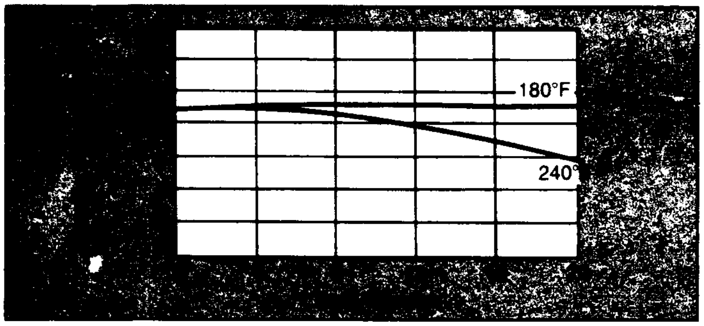


FIGURE 16
EFFECT OF HEAT AGING ON NOTCHED IZOD IMPACT STRENGTH

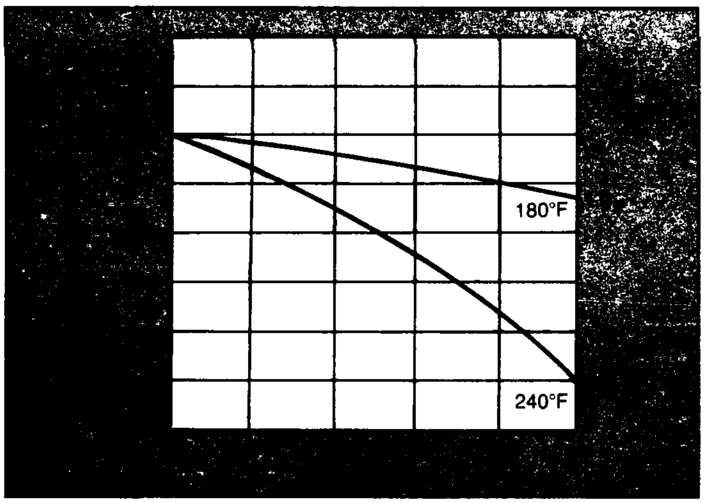


FIGURE 17
EFFECT OF HEAT AGING ON MELT INDEX AT 180°F

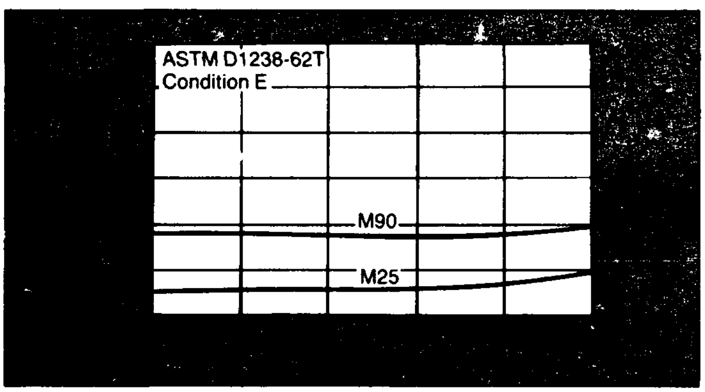


FIGURE 18
EFFECT OF HEAT AGING AT 180°F TENSILE IMPACT STRENGTH

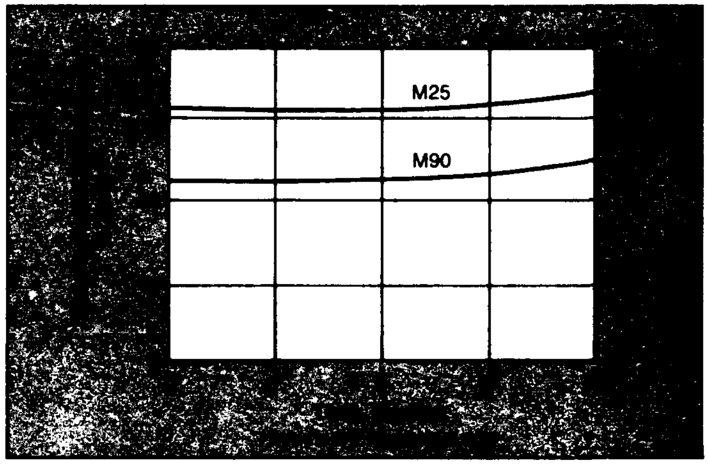
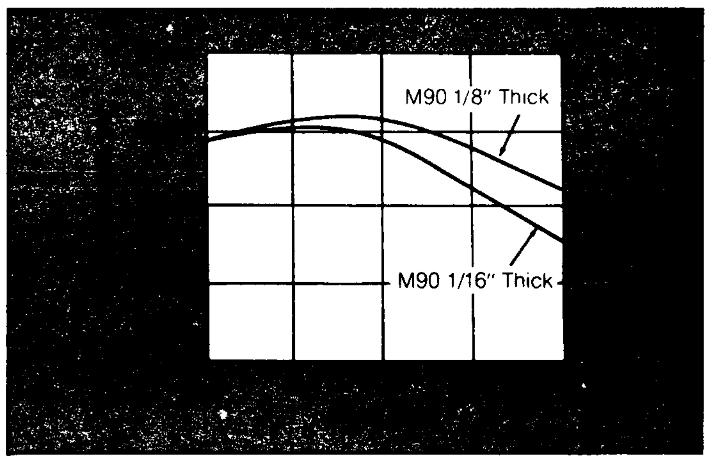


FIGURE 19
HIGH TEMPERATURE HEAT AGING TENSILE STRENGTH VS. TIME AT 280°F



to Celcon acetal copolymer. Others, like ultra-violet rays in sunlight, may not be damaging in small amounts but require different formulations to permit continuous exposure.

AGING IN HOT AIR

Injection molded specimens of Celcon aged in air at 180°F, 240°F and 280°F were tested for mechanical properties at intervals. Results of standard testing are shown in Figures 15-19.

Tensile strength, izod impact and tensile impact are virtually unchanged after aging at 180°F for 20 months for both Celcon M90 and M25. After aging at 240°F, both Celcon M90 and M25 show a slight fall off in tensile strength after 12 months and a decrease of approximately 40 percent after 20 months. The fall off in Izod impact after aging at 240°F is greater than at 180°F for both Celcon M90 and M25. These data are shown in Figure 16. Long-term flexural creep data are presented in a later section of this bulletin.

AGING IN HOT WATER

Exceptional resistance to long term hot water exposure is a primary reason why Celcon acetal copolymer is so widely used for plumbing. After a year in water at 180°F, most properties of Celcon are virtually unchanged and after two years, only a moderate decrease is observed. Samples of Celcon, in boiling water, retained nearly all of their original tensile strength after nine months (Figure 25).

The above testing was done on laboratory injection molded bars under conditions such that a gradual change-over in the water supply resulted. A week to ten days was needed for a complete change of water. Typical results appear in Figures 20-26. Celcon is not recommended in closed loop systems where the water may become stagnant or is not replenished. Table 7 on Page 30 lists the various specifications such as NSF, RHDS and ASTM with which Celcon complies.

FIGURE 20
CHANGE IN LINEAR DIMENSIONS WITH MOISTURE CONTENT, 73°F & 50% R.H.

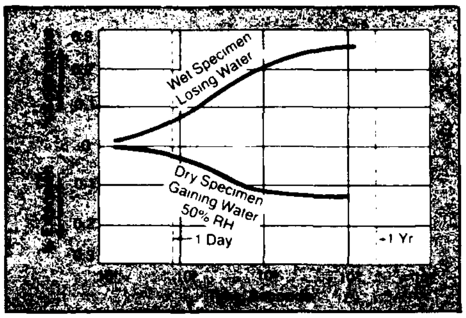


FIGURE 21
TENSILE STRENGTH VS. TIME IN HOT WATER (180°F)

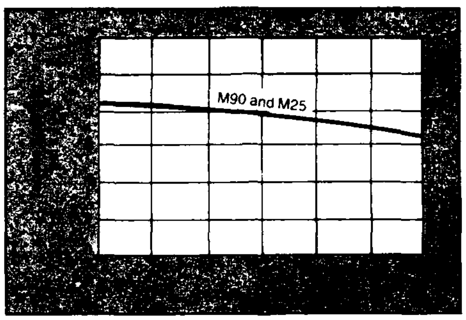


FIGURE 22
MELT INDEX VS. TIME IN HOT WATER (180°F)

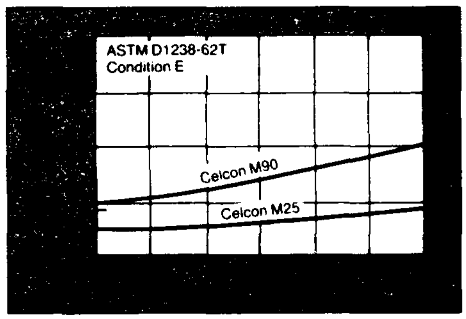


FIGURE 23
TENSILE MODULUS VS. TIME IN HOT WATER (180°F)

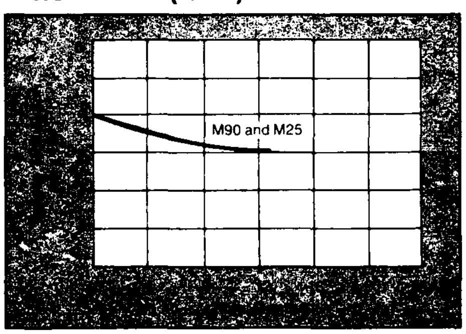


FIGURE 24
***NOTCHED IZOD IMPACT RESISTANCE* VS. TIME IN HOT WATER (180°F)**

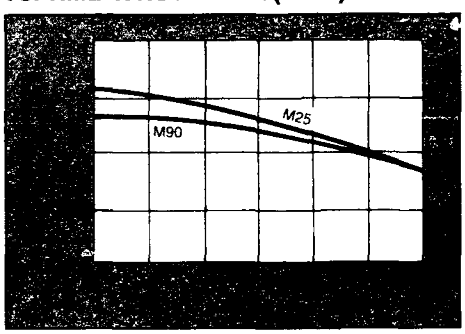


FIGURE 25
***TENSILE STRENGTH* VS. TIME IN BOILING WATER**

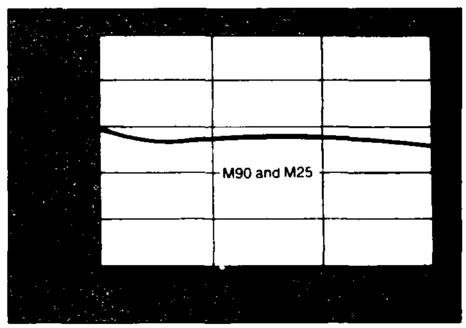
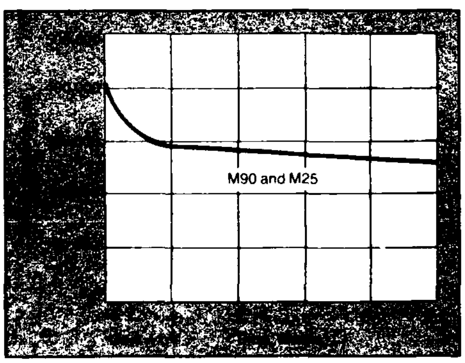


FIGURE 26
TENSILE MODULUS VS. TIME IN BOILING WATER



WEATHERING RESISTANCE

Many applications require that Celcon acetal copolymer parts withstand exposure to sunlight through use in naturally lighted areas or in outdoor applications. All plastic materials are affected by ultraviolet light exposure and suffer a certain amount of degradation. The degradation usually is noticed by fading, chalking and embrittlement.

Natural and pigmented standard Celcon grades are not recommended for applications where prolonged ultraviolet exposure is encountered. Special U.V. stable packages are available as the UV90 and UV25 grades. These materials are available in natural and colored versions (precompounded or color concentrate letdown). UV90 colors and M90-CD3068 black are especially recommended for applications involving U.V. exposure. Figures 27 to 29 show the effect of outdoor exposure on natural Celcon M90, U.V. stabilized natural Celcon UV90, and M90-CD3068 black physical properties. Figure 30 shows the effect of outdoor exposure on GC25A black. Special black weather resistant grades of M90 and M25 designated WR90 and WR25 have been developed for maximum weathering resistance for outdoor applications. Figure 31 shows the resistance of WR25 and WR90 to color change and fading vs. M90-CD3068 black in a QUV weathering test apparatus. The color retention indicates the WR grades will have excellent long-term property retention in outdoor applications. More severe weathering tests are in progress. Contact your local Hoechst Celanese Engineering Plastics Division sales office for updated information.

U.V. stabilized UV90 colors and M90-CD3068 black are recommended for use in U.V. resistant applications such as automotive interiors, lawn sprinklers, toys, and boating accessories. For maximum weathering resistance, WR25 and WR90 are recommended for outdoor applications such as irrigation gates, permanent watering systems, exterior door handles and hardware for automobiles, RV's, campers, boats and snowmobiles.

FIGURE 27
TENSILE STRENGTH VS. OUTDOOR EXPOSURE (ARIZONA AND NEW JERSEY)

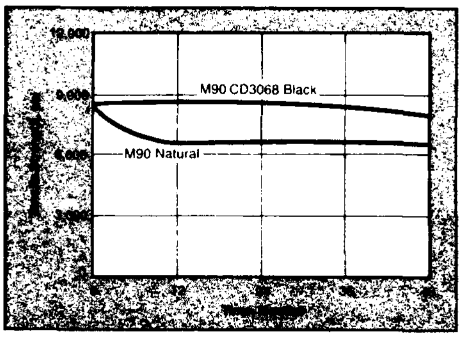


FIGURE 30
EFFECT OF OUTDOOR EXPOSURE NEW JERSEY ON TENSILE STRENGTH

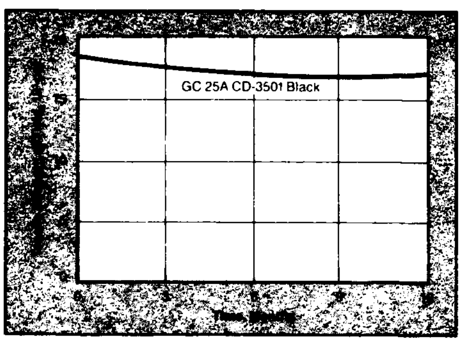


FIGURE 28
MELT INDEX VS. OUTDOOR EXPOSURE (ARIZONA AND NEW JERSEY)

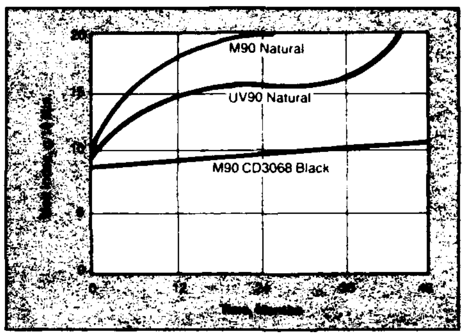


FIGURE 29
TENSILE IMPACT VS. OUTDOOR EXPOSURE (ARIZONA AND NEW JERSEY)

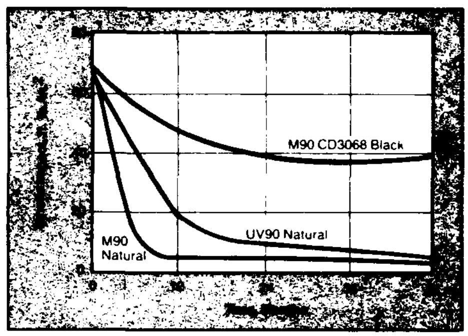
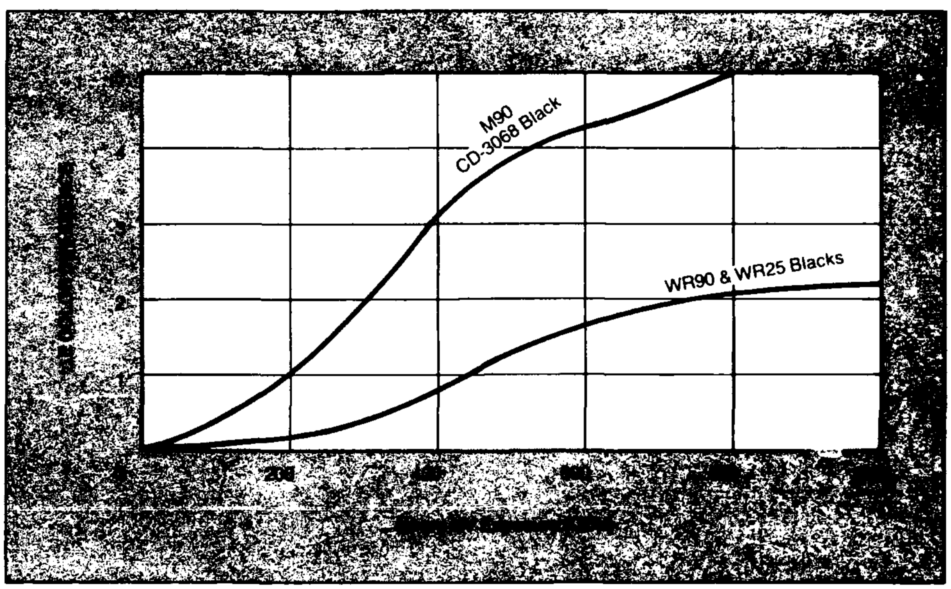


FIGURE 31
COLOR AND SURFACE APPEARANCE RETENTION VS. QUV EXPOSURE CELCON M90 BLACK AND WR90



PERMEABILITY

Vapors permeate plastics at rates depending on the kind of plastic, thickness, and temperature. Permeability characteristics for Celcon acetal copolymer appear in Figure 32.

FIGURE 32
GAS PERMEABILITY OF CELCON M25, M90, M270 @ 73°F.

Material	Units	Gas Transmission Rate (P-Factor) @ 73°F
Air	cc-mil 24 hr/atm/100 sq. in. (Measured on 6 mil film)	2.2-3.2
Nitrogen		2.2-3.2
Oxygen		5.0-7.4
Carbon Dioxide		144-174

CHEMICAL RESISTANCE

Celcon acetal copolymer has excellent chemical resistance to many chemicals when tested in an unstressed state.

After twelve months immersion at room temperature in various inorganic chemicals, Celcon was little affected except by strong mineral acids (sulfuric, nitric, hydrochloric), and strong oxidizing agents such as aqueous solutions of high concentrations of hypochlorite ions. *Celcon is not recommended for use in* the presence of mineral acids. Prolonged or continuous use of Celcon in aqueous solutions of higher than 1 ppm hypochlorite ions is also not recommended. Aqueous solutions of hypochlorite ions, however, can be used at concentrations normally used for sterilization purposes if the system is well flushed after the specified sterilization time. Continuous use of Celcon in the presence of hypochlorite ions should be limited to low concentrations such as found in ordinary drinking water. Solutions of 10% ammonium hydroxide, 3% hydrogen peroxide, and 10% sodium chloride at room temperature discolored samples in prolonged immersion but no serious changes in Celcon physical properties occurred.

Most organic reagents tested do not affect Celcon. Test results are indicated in Table 6.

Celcon is unaffected by washing in common solvents such as acetone, ethyl alcohol, and lacquer solvents at room temperature. In addition, oils such as mineral oil ("Nujol"), motor oil (10W30 "Uniflow"), and brake fluids (Super "9" and Lockheed "21") produced little change in properties.

Celcon is exceptionally resistant to strong alkalies. Specimens of Celcon have been immersed in boiling 50% sodium hydroxide solution and other strong bases for many months, and showed little change.

Immersion at 73°F in various water solutions having pH values ranging from 4 to 14 produced no significant changes. Celcon retained its high strength properties, including high tensile and flexural strength and stiffness. Similar tests at 180°F for 6 months in manufacturer's recommended solution of "Electro-Sol" home dishwashing compound and "Calgonite," a water softener, and 3 months *in the "Acclaim"* commercial dishwashing compound, produced no change in tensile strength of Celcon. In the presence of aqueous solutions at elevated temperatures for a month or more, Celcon may change color. However, the change in color is not related to any change in physical properties. In some cases, the color change is only a surface phenomenon and readily washes off with water. Table 6 summarizes tests showing effects of long-term immersion at room temperature and in many cases at 120°F and 180°F. Dimensional changes with moisture picked up during long-term immersion in 73°F water are shown in Figure 20.

Mixing screws

TABLE 6
CHEMICAL RESITANCE OF CELCON M90, M25, M270

Material	Time Months	Temp. °F.	%Change Yield Strength	%Change Tensile Modulus	%Change' Length	%Change Weight	Visible Effect'
Control (Air)	12	73	0	0	0	0.22	N.C.

INORGANIC CHEMICALS

Material	Time Months	Temp. °F.	Yield Strength	Tensile Modulus	%Change' Length	Weight	Visible Effect'
10% Ammonium Hydroxide	6	73	0	0	0.3	0.88	Disc.
	12	73	0.7	−16	0.3	1.03	Disc.
	6	180	−0.3	−12	0.4	0.74	Disc.
[redacted]							
10% Hydrochloric Acid	6	73	x	x	x	x	x
10% Nitric Acid	6	73	x	x	x	x	x
[redacted]							
1% Sodium Hydroxide	6	73	1	2	0.2	0.80	N.C.
	12	73	2	2	0.2	0.84	N.C.
10% Sodium Hydroxide	6	73	1	− 8	0.2	0.49	N.C.
	12	73	−2	− 6	0.2	0.73	N.C.
	6	180	−3	− 8	0.2	0.83	Sl.Disc
60% Sodium Hydroxide	6	180	−3	− 6	−0.1	−0.18	Sl.Disc
4.6% Sodium Hypochlorite	6	73	x	x	x	x	x
26% Sodium Thiosulfate	6	180	3	−12	0.2	0.61	N.C.
[redacted]							
Buffer, pH 7.0	6	180	2	−15	0.3	0.94	Sl.Disc
Buffer, pH 10.0	6	180	4	−12	C.3	0.89	Sl.Disc
Buffer, pH 4.0	4	180	x	x	x	x	x
Water (Distilled)	6	73	0	−12	0.2	0.83	N.C.
	12	73	4	−12	0.2	0.84	N.C.
	12	180	0	−18	−0.1	− 3.32	Disc.

ORGANIC CHEMICALS

Material	Time Months	Temp. °F.	Yield Strength	Tensile Modulus	%Change' Length	Weight	Visible Effect'
5% Acetic Acid	6	73	− 1	−15	0.3	1.05	N.C.
	12	73	0.6	−16	0.2	1.13	N.C.
[redacted]							
Aniline	6	180	−26	−73	4.8	12.1	Reddish Tint
Benzene	6	120	−17	−43	1.8	3.93	N.C.
Carbon Tetrachloride	6	73	− 1	− 4	0.2	0.86	N.C.
	12	73	2	− 6	0.1	1.39	N.C.
	6	120	−11	−32	1.2	5.23	N.C.
[redacted]							
Diethyl Ether	6	73	−15	−26	1.1	2.09	N.C.
Dimethyl Formamide	6	180	−19	−63	3.1	7.7	N.C.
Ethyl Acetate	6	73	− 5	−20	0.6	3.62	N.C.
	12	73	−17	−46	1.6	4.25	N.C.
	6	120	−22	−50	2.1	5.23	N.C.
[redacted]							

TABLE 6 Continued

Material	Time Months	Temp. °F.	%Change[1] Yield Strength	Tensile Modulus	Length	Weight	Visible Effect[3]
ORGANIC MATERIALS Continued							
50% Ethanol	6	73	−4	−24	0.6	1.62	N.C.
	12	73	−5	−32	0.7	1.98	N.C.
	6	120	−13	−34	1.0	2.27	N.C.
[redacted]							
Oleic Acid	6	73	−1	−15	0.3	0.15	N.C.
	12	73	3	31	−0.04	1.26	N.C.
	6	180	0	−9	0.5	1.04	N.C.
[redacted]							
Toluene	6	73	−7	−17	0.4	1.12	N.C.
	12	73	−7	−19	0.7	1.87	N.C.
	6	180	−14	−43	1.6	3.80	N.C.
OTHER MATERIALS							
Automatic Transmission Fluid		180	5	5	−0.07	−0.15	N.C.
Anti-Freeze (Telar)	6	180	0	−23	0.6	1.53	N.C.
Brake Fluid, "Super 9"	6	73	0	−12	0.3	0.34	N.C.
	12	73	3	−1	0.2	0.53	N.C.
Brake Fluid, Lockheed "21"	6	73	−3	−13	0.3	0.70	N.C.
	12	73	−0.5	−9	0.2	1.05	N.C.
	6	180	−11	−41	1.4	3.60	N.C.
Brake Fluid, "Delco 222"	6	180	−5	−33	1.3	3.18	N.C.
[redacted]							
Gasolines							
Mobil Reg. (93/5 Octane)	6	120	−11	−12	0.7	1.30	N.C.
Mobil "Hi-Test" (99.0 Oct.)	6	120	−12	−12	0.7	1.50	N.C.
Sunoco "280" (103 Octane)	6	120	−6	−10	0.7	1.43	N.C.
[redacted]							
Motor Oil (10W30)	6	73	−1	−9	0.2	0.02	N.C.
	12	73	5	7	−0.06	0.04	N.C.
	6	180	5	0	−0.06	−0.14	N.C.
[redacted]							
Diesel Fuel, Fuel C	6	160	−8	−32	0.99	2.44	N.C.
	12	160	−10	−33	1.04	2.39	N.C.

1. Type 1 Tensile bars used in these tests measure 8½x½x⅛ inches; initial yield strength is 8800, tensile modulus 410,000; weight 13 grams.
2. Consists of 0.5 grams of an alkyl sulfonate +0.20 grams of trisodium phosphate per liter of water.
3. x = Not recommended; N.C. = No Change; Disc. = Discoloration; Sl. Disc. = Slight discoloration.

AGING UNDER LOAD

Parts of Celcon acetal copolymer continuously under load have good resistance to creep, and their dynamic fatigue behavior is excellent.

Creep Creep, also called cold flow, refers to dimensional changes (strain) occurring in continuously stressed plastics after initial deformation. Although dependent on temperature and the time under stress, both creep behavior and elastic recovery from deformation characteristics can be accurately predicted.

Flexural Creep. Deflection, with time, of center loaded beams of Celcon acetal copolymer was recorded at various temperatures and different stress levels. The following equation was used to calculate stress:

$$S = \frac{3PL}{2bd^2}$$

S = Fiber stress

P = Concentrated load in lb.

L = Span in inches between end supports

b = Beam width, inches

d = Beam thickness, inches

Resulting data are plotted in Figures 33 and 34.

Apparent Modulus vs Temperatures for Different Time Intervals. Established equations of stress analysis developed for metals may be used in plastics engineering design with reasonable predictability.

An Apparent Modulus must be used in place of Young's Modulus in these equations to obtain realistic results. From experimental creep data a set of Apparent Modulus curves have been developed so that the appropriate Apparent Modulus can be selected for calculation based on time and temperature of constant load which the plastic is expected to support. These curves appear in Figures 35 and 36.

Compressive Creep. Compressive creep was determined by holding ½-inch cubes of Celcon acetal copolymer under continuous load (at various selected levels) and measuring creep. Room temperature compressive creep is negligible. Data for 160°F (Figure 37) show the remarkable performance of Celcon loaded at 1000 and 4000 psi.

Stress Relaxation. Creep behavior was further characterized by placing samples of Celcon under selected levels of strain and measuring changes in stress with time. Results, plotted in Figure 38, are useful in predicting behavior of parts of Celcon acetal copolymer subjected to constant levels of strain.

Tensile creep at various loadings appear in Figures 39 (68°F) and 40 (140°F).

FIGURE 33
FLEXURAL CREEP AT 500 PSI FIBER STRESS (CELCON M90)

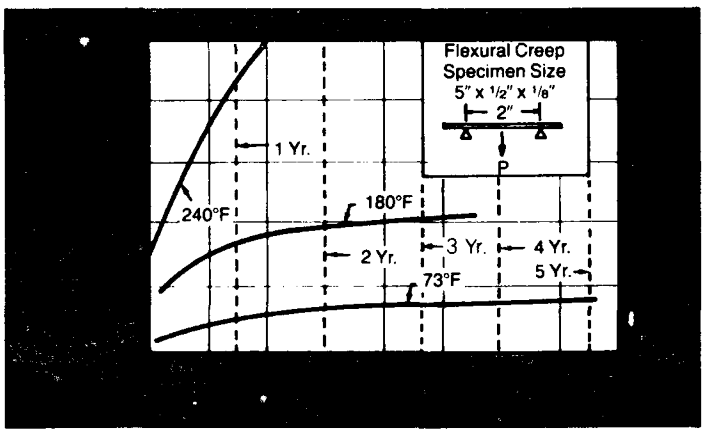


FIGURE 34
FLEXURAL CREEP AT 73°F, 50% R.H. 5000 PSI FIBER STRESS (CELCON M90)

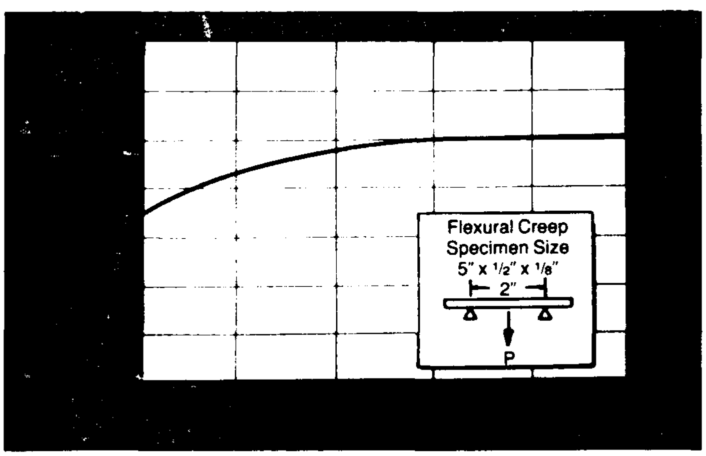


FIGURE 35
APPARENT FLEXURAL MODULUS VS. TEMPERATURE (CELCON M90)

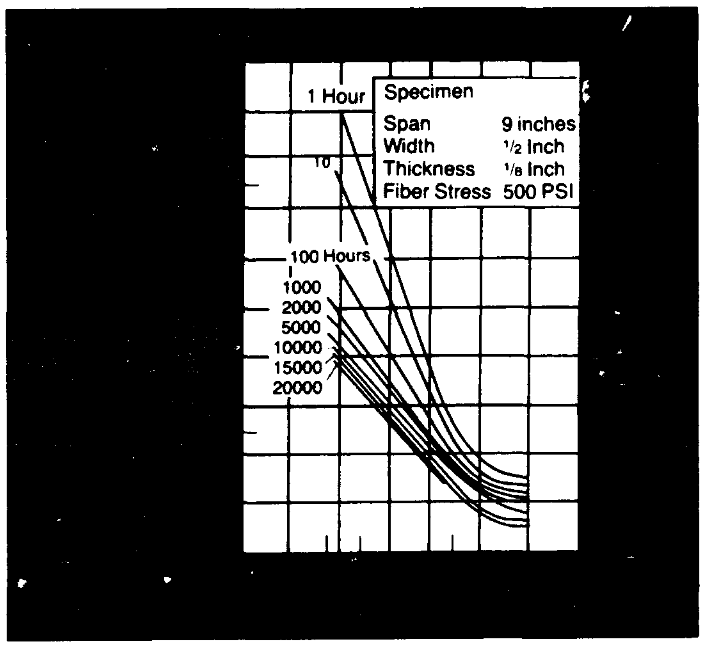


FIGURE 36
APPARENT MODULUS VS. TIME 500 PSI FIBER STRESS (CELCON M90)

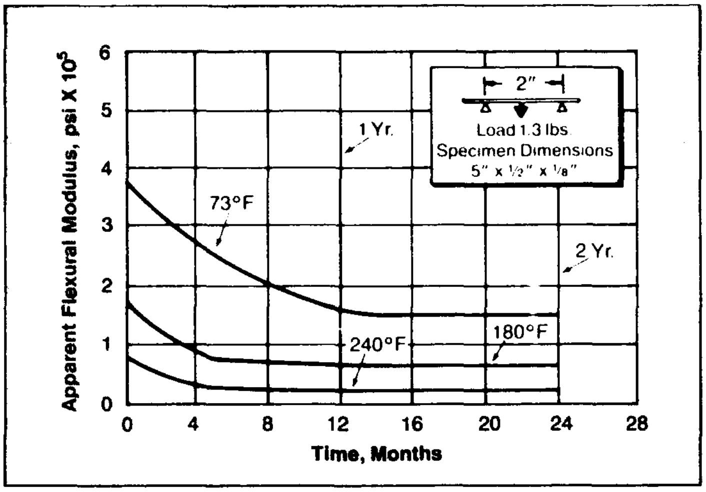


FIGURE 37
CREEP IN COMPRESSION AT 160°F (CELCON M90)

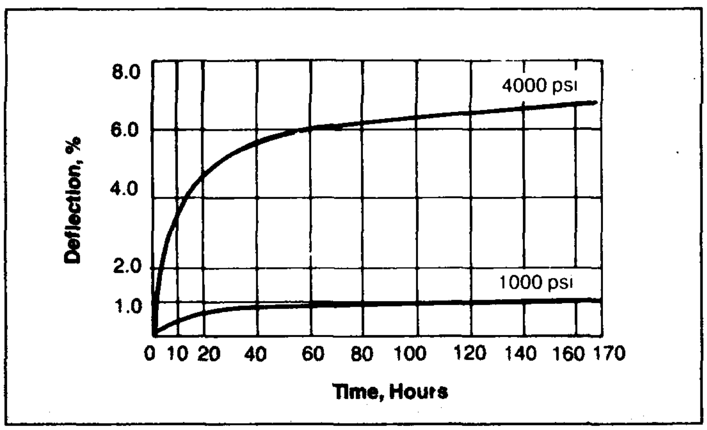


FIGURE 38
TENSILE STRESS RELAXATION, CONSTANT STRAIN AT 68°F (CELCON M90)

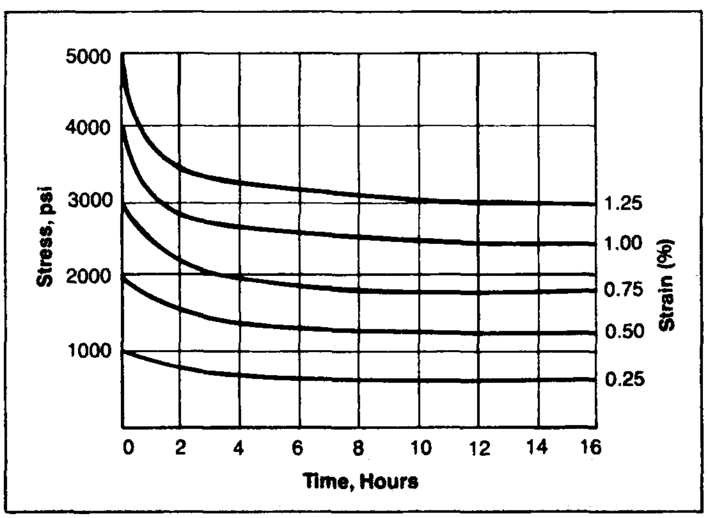


FIGURE 39
TENSILE CREEP AT 68°F, 70% R.H. (CELCON M90)

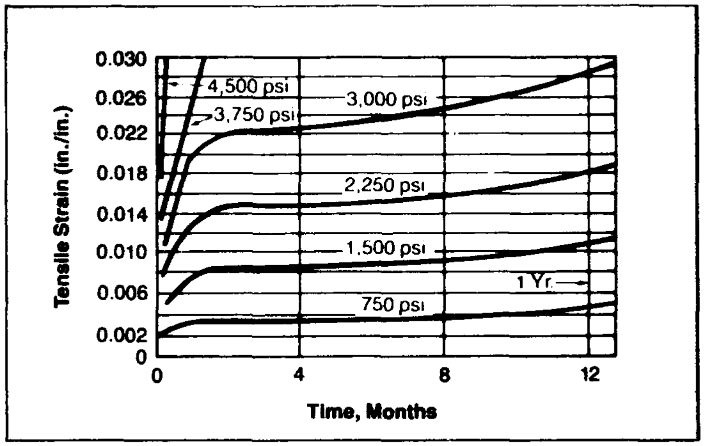
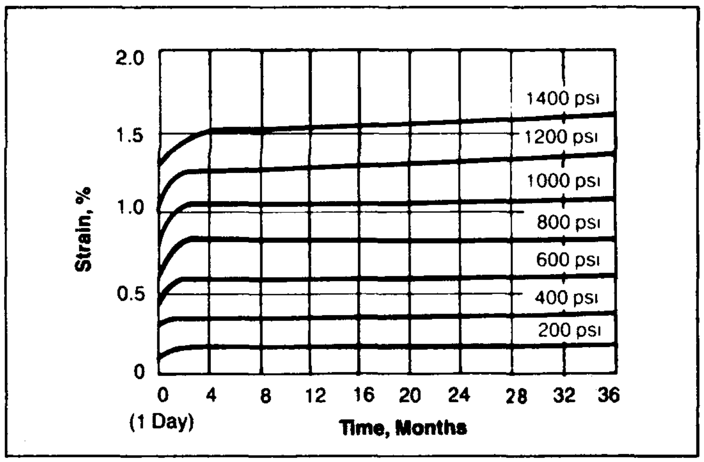
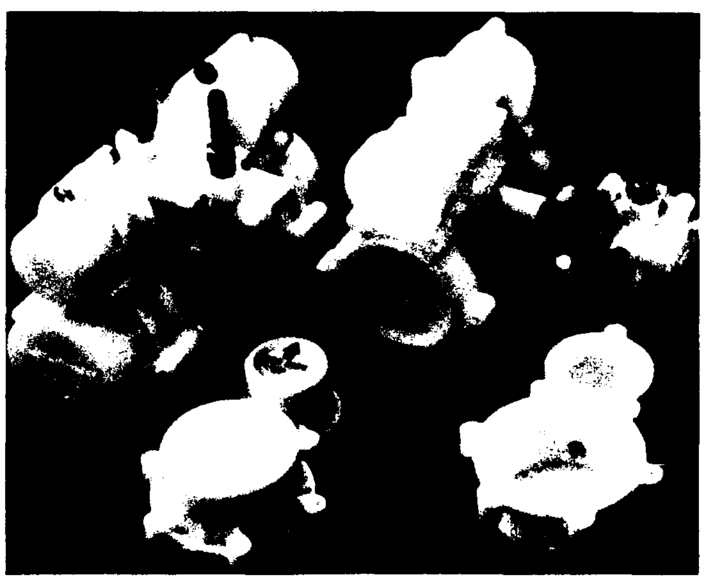


FIGURE 40
CREEP IN TENSION AT 140°F (CELCON M90)





Soft Drink Dispensing Pump

FATIGUE ENDURANCE

Because of its highly crystalline polymer structure, Celcon acetal copolymer has exceptional resistance to tensile and flexural fatigue stress. However, fatigue from repeated loading can eventually cause failure of a part in service. It is important in designing gears, hinges, and other reciprocating mechanical parts to design for sufficient strength to prevent fatigue failure.

Laboratory fatigue data on Celcon specimens is presented in Figures 41-43. Under metal fatigue endurance limits, which are defined as stress at which specimens fail at 10^7 cycles, Celcon acetal copolymer can be said to have a flexural fatigue endurance limit of 3300 psi at 73°F and 50% RH with cantilevered specimen shown in Figure 41. With center loaded beams, as shown in Figure 42, flexural fatigue is 4300 psi. Flexural fatigue data were obtained on a Budd fatigue tester.

Tensile fatigue endurance limit of Celcon acetal copolymer at similar conditions is 4200 psi. Tensile fatigue life was determined on a Sonntag Universal Fatigue Tester. Specimens and results are shown in Figure 43.

FIGURE 41
FLEXURAL FATIGUE STRESS (ALTERNATING) VS. CYCLES TO FAILURE (CELCON M90)

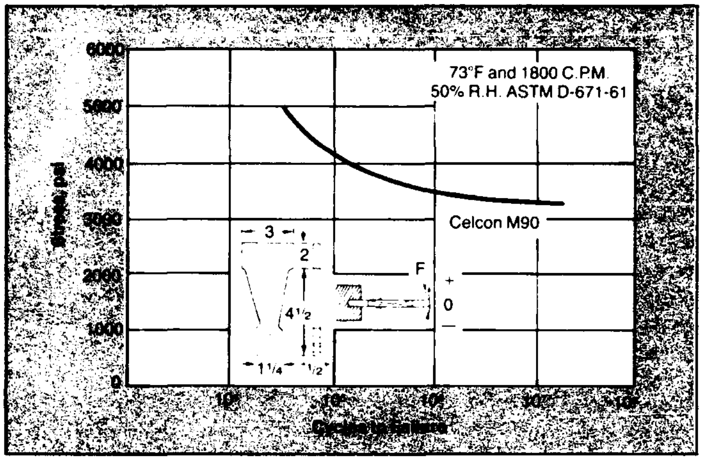


FIGURE 42
FLEXURAL FATIGUE CURVE (CELCON M90)

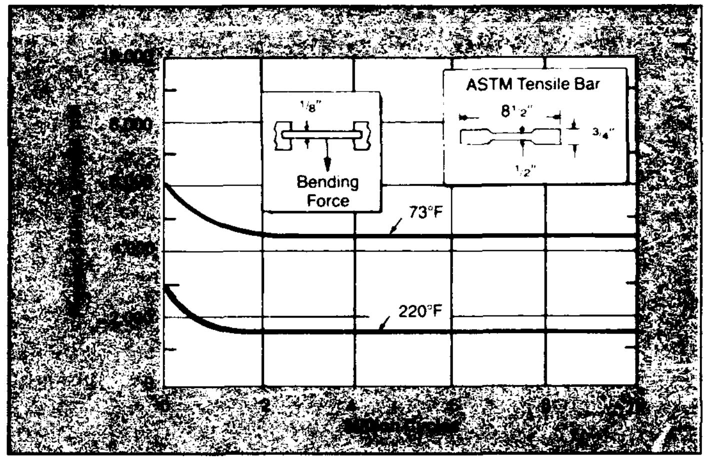
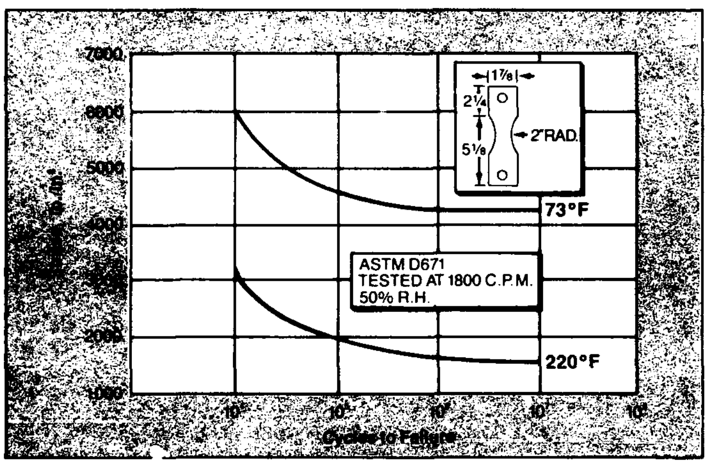
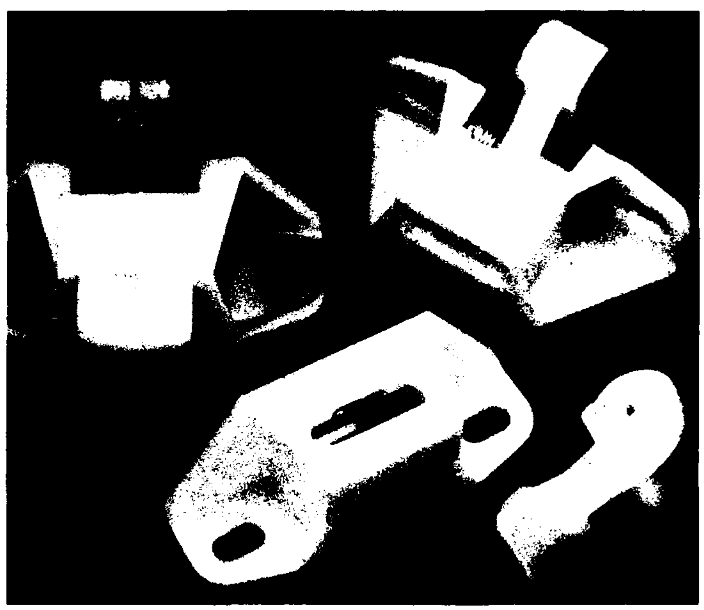


FIGURE 43
TENSILE FATIGUE STRESS VS. CYCLES TO FAILURE





Automotive Door Lock Parts

STORAGE, HANDLING AND SAFETY

STORAGE AND HANDLING

Standard shipping containers for Celcon plastics are multi-wall bags holding 25 kg of free-flowing pellets, and 500 kg boxes.

In storage, it is advisable to keep Celcon dry so that it can be processed directly from the package. Celcon acetal copolymer does not absorb appreciable moisture from the atmosphere, but small amounts absorbed during long storage at high humidity can cause surface blemishes on molded parts.

Drying, if required, can be accomplished by the use of conventional hopper/dryers or convection ovens. For details refer to Hoechst Celanese Bulletin CE-3A on "Injection Molding Celcon."

RECYCLING SCRAP

Celcon acetal copolymer may be re-extruded or remolded more times than many other materials with no significant change in processing characteristics or physical properties. After repeated reworking—especially if high heats are used—the material will darken and eventually appear brown. Remolding can continue until the brown discoloration exceeds acceptable appearance limits; physical properties such as tensile strength, elongation, and stiffness remain essentially unchanged. Limiting regrind use to 25% aids in maintaining color uniformity, and is generally recommended. It is usually advisable to dry re-ground material before use.

SAFETY PRECAUTIONS

Celcon acetal copolymer should never be left standing in a processing machine for long periods of time at high temperature. This is generally true of all thermoplastic resins. The presence of a brown discoloration of the material and strong formaldehyde odors in the atmosphere indicate the material temperature is too high, and immediate steps should be taken to lower the material temperature and purge discolored material from the machine. Purged material should be dropped into water to reduce the amount of vapors released in the work area.

Celcon acetal copolymer should not be heated above 460°F (240°C) nor permitted to remain in a heated chamber for long periods of time at temperatures above 380°F (193°C).

Excessively high temperatures or long residence time in a heated chamber at lower temperatures can cause the resin to discolor and, in time, volatilize the resin, liberate formaldehyde, and produce pressures in the chamber sufficient to blow back through the feed area. If no exit is available for these gaseous products, pressure could develop which might rupture the machine and injure personnel. It is to insure satisfaction in the use of Celcon, as well as to avoid possible damage to equipment and injury to personnel that these guides are presented.

See Celcon Material Safety Data Sheet for detailed safety information available from our Engineering Plastics Division Technical Information Center, Chatham, N.J. (201) 635-4393.

WARNING—PVC

PVC (polyvinyl chloride) forms acidic decomposition products on heating which can rapidly degrade Celcon at processing temperatures. Celcon acetal copolymer and PVC are mutually destructive and must never be allowed to mix even in trace quantities in a machine. It is strongly recommended that close control is exercised to ensure that there is no chance of contamination of feed stocks. If at all possible, Celcon and PVC should never be run through the same machine. If this is unavoidable, purging with acrylic or polyethylene followed by thorough manual cleaning is imperative.

METAL CONTACT

Celcon plastic remains stable at molding temperatures in the presence of copper, zinc, iron, nickel, lead, brass and bronze. It can be molded satisfactorily in molds containing copper alloys.

VENTILATION

Most polymers, when heated to very high temperatures, will tend to decompose and give off decomposition products. Celcon is no exception.

When heated above recommended molding conditions, Celcon can release small quantities of formaldehyde. If sufficient concentrations are allowed to build up over prolonged periods due to insufficient ventilation, these could be harmful. It is therefore recommended that all heating and processing operations involving Celcon be carried out in areas with adequate ventilation.

For more detailed information on worker exposure limits for formaldehyde, refer to the Material Safety Data Sheet (MSDS) for Celcon acetal copolymer.

The time required for discoloration of material (and possible release of excessive formaldehyde odors) is roughly related to material temperature as follows.*

Material F	Temperature C	Time to Discoloration Minutes
375	190	110-120
400	204	65- 75
425	270	35- 45

*The screw was stopped in a machine and heats left on at indicated temperatures. Samples at 15 minute intervals were obtained during brief starts and the total time to discoloration recorded.

These figures are based on material temperatures and are intended to serve as a guide in machine operations. None of these tests showed any significant change in melt index or physical properties. However, material residence time in the machine should always be kept to a minimum.

START-UP PROCEDURES

The nozzle temperature should be set at 390-420°F (199-216°C) and the cylinder temperature at 365-380°F (185-193°C). Celcon pellets should be fed to the machine through the hopper, and purging started. Purged material should be dropped into water to reduce fumes. If the material leaving the nozzle becomes cold, purging must be stopped for a short time to allow the material passing through the cylinder to become molten; material being rapidly purged through the machine may not reach the set temperatures. After the cylinder has been filled with Celcon resin, normal molding can begin and the required temperature adjustments made.

The material should be kept moving through the cylinder, particularly when small moldings are being made on a larger machine. If there is an appreciable delay in the molding process, the machine should be purged at intervals of about 10 minutes; the interval which should be used may be determined by observing the degree of discoloration of the material at each purging

SAFETY PRECAUTIONS (Continued)

Whenever possible the cylinder should be retracted from the mold during stoppages to prevent the material from freezing and blocking the nozzle. If a long delay is expected, the machine should be shut down and restarted following the procedure outlined below.

It is important to ensure that the nozzle is not blocked, and therefore the nozzle temperature should be set at 390-420°F (199-216°C) and the cylinder temperature at 250-275°F (121-135°C). As soon as the nozzle reaches the set temperature, the cylinder temperature may be raised to 365-380°F (185-193°C). When the cylinder has reached this temperature a few purging shots may be made at low pressure, and molding may be commenced when it has been ascertained that there are no blockages in the cylinder or nozzle.

When Celcon is to be molded in a machine after another material has been molded, the procedure is as follows. If the material previously in the cylinder melts at temperatures above the molding temperature range of Celcon resin (e.g., nylon) or has poor heat stability at acetal processing temperatures (e.g., Cellulose Acetate) or is incompatible with Celcon resin, the cylinder must first be purged with a material such as polyethylene or acrylic, which is stable at high temperatures and molten at acetal processing temperatures. After removal of the material with either higher melt temperatures or poor heat stability, the cylinder temperatures must be set at 365-380°F (185-193°C) and the Celcon resin may then be fed to the machine through the hopper. Molding can begin when the copolymer alone is coming from the nozzle and the required molding conditions can then be set.

If the material in the cylinder does not have a higher melting temperature or less heat stability, or is not incompatible with Celcon resins, (i.e., polyethylene) the cylinder temperatures may be set at 365-380°F (185-193°C) and the Celcon resin may be fed to the machine through the hopper.

When another material is to follow Celcon in the machine, the same considerations apply as in the previous section. When the material to follow Celcon resin requires higher cylinder temperatures, or is unstable with or at acetal copolymer processing temperatures, an intermediate purging material must be used to clear the acetal copolymer from the cylinder.

If the acetal copolymer is in the barrel when the machine is started, the instructions given under "Starting with Celcon Acetal Copolymer in the Cylinder" should be followed. (See Bulletin CE-3A, Injection Molding Celcon.)

SHUT-DOWN PROCEDURE

The nozzle temperature should be set at 390-420°F (199-216°C) to prevent premature freezing, the heaters on the cylinder should be switched off and molding on cycle or purging should be continued until all the heating zones of the cylinder are reduced to 350°F (177°C) or less. The nozzle heater may then be switched off and the machine stopped. If, due to the design of the machine, the flow of material ceases before the cylinder temperature falls to 350°F (177°C) the machine should be purged with polyethylene, polypropylene or polystyrene before being switched off. As noted under "Safety Precautions" all purgings containing acetal copolymer should be dropped into water to minimize fumes.

FLAMMABILITY

When ignited, Celcon acetal copolymer burns with little or no smoke, and with a barely visible blue flame. The material burns cleanly when combustion is complete, yielding carbon dioxide and water and virtually no ash. If Celcon burns with a muffled flame, however, and combustion is not complete, carbon monoxide and some formaldehyde may be given off. Formaldehyde is a colorless, pungent gas which can be harmful in exposure to high concentrations. Formaldehyde is very irritating and voluntary exposure to harmful concentrations is unlikely.

Some idea of the rate at which Celcon burns when held in a horizontal position, as a function of part thickness, may be obtained from the results of the following test, described in Federal MVSS (Motor Vehicle Safety Standard) 302:

A plaque 4 in. wide × 14 in. long in the thickness to be tested is supported horizontally on three of its four edges in a U-shaped metal frame mounted inside a metal cabinet to prevent drafts. The one (4 in. wide) unsupported edge is ignited at its center, and the rate of burning of the plaque along its length is monitored.

The results obtained on Celcon M Series Natural, at various thicknesses, indicate that burning rate decreases rapidly as thickness increases, and at 0.060 inch thickness, which is generally the minimum for most articles molded of Celcon, the rate is already quite low (1.1 in./min.). Federal Specification MVSS-302 requires a maximum burning rate of 4 in./min.

Tested per ASTM D635, using a ⅛ inch thick specimen, Celcon M90 has a burning rate of 1.1 in./min., virtually the same as that for other common materials such as polyethylene, polystyrene, and slow burning woods. UL rates the material HB (Horizontal Burning) down to 0.028" in the UL 94 Flammability Test. Celcon M90 has an LOI (Limited Oxygen Index) of 15.

While standard flammability tests are generally useful in characterizing the burning behavior of materials as they relate to one another, they rarely reflect the true performances of the materials in a real fire situation. Concern for flammability hazards increases as the size of the parts involved increases. With this in mind, Celanese conducted a series of practical flammability tests on a lavatory injection molded of Celcon installed in a vanity. Conclusions drawn from these tests were that the lavatory would not ignite easily except by the direct application of a flame. Even when ignited, the lavatory burns at a relatively slow rate and with a flame which, though barely visible, is readily extinguished. A copy of the report on these tests, entitled, "Flammability of Lavatories Molded of Celcon," may be obtained upon request.

SPECIFICATIONS AND REGULATORY APPROVALS

In addition to the unique engineering properties of Celcon resins, many product grades meet various industry standards and governmental regulations defining plastic usage in demanding end-use applications. Those regulations and standards applicable to Celcon are shown in Table 7. For detailed information on the qualifications of specific Celcon grades and formulations, contact our Engineering Plastics Division Technical Information Center, Chatham, N.J. (201) 635-4393.

TABLE 7

Government and Regulatory Agencies	
ASTM D-4181	General Material Specification
Food and Drug Administration (FDA)	Food contact applications which conforms to 21 CFR 1772470
National Sanitation Foundation (NSF)	Potable water contact items and food machinery components NSF Standards 14 & 51
Underwriters Laboratory (UL) properties	UL ratings for flammability, electrical and thermal use properties
ASTM-17-2133 LP-392-a MIL-P-46137A(MR)	Superseded by ASTM D-4181
Dairy & Food Industries Supply Association (DFISA)	3A Sanitary Standards for contact with dairy products
United States Department of Agriculture (USDA)	Approved for use in direct contact with meat and poultry products
Plumbing Code Bodies	
International Association of Plumbing & Mechanical Officials (IAPMO) Building Officials Conference of America (BOCA) Southern Standard Building Code	Plumbing fixtures and specific applications covered in the various codes
Canadian Standards Association (CSA)	Plumbing fixtures, fittings and potable water contact items
Plastic Pipe Institute (PPI)	Recommended Hydrostatic Design Stress (RHDS) rating of 1000 PSI at 73° as an injection molded plumbing fitting

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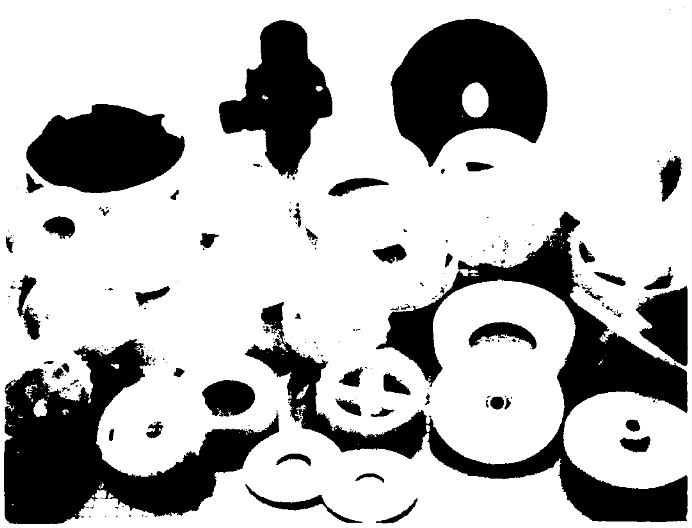
PRODUCT PLANNING & TECHNICAL SUPPORT

- Material selection
- Color development & matching
- Part design assistance
- Prototype design assistance
- Mold design assistance
- Part and tool cost estimates
- Performance testing (customer advice only)
- Pilot production recommendations
- Process equipment recommendations
- Injection molding support
- Prototyping

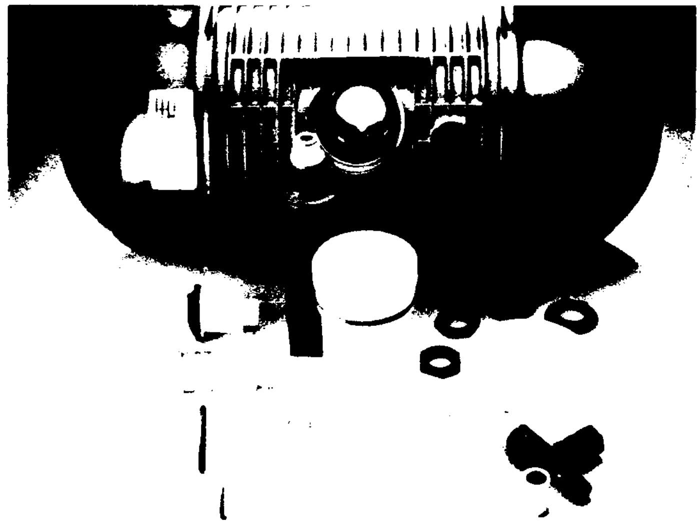
INFORMATION SYSTEMS

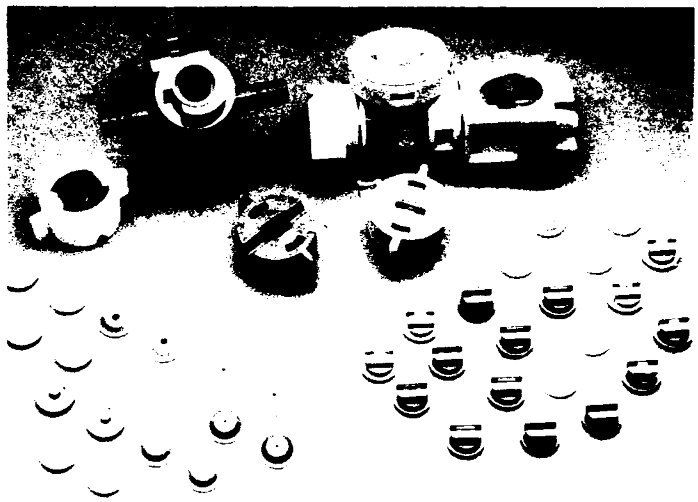
- Technical library
- Customer technical service
- Technical data & bulletins
- UL & Regulatory information

CELCON ACETAL COPOLYMER VERSATILITY IN PERFORMANCE

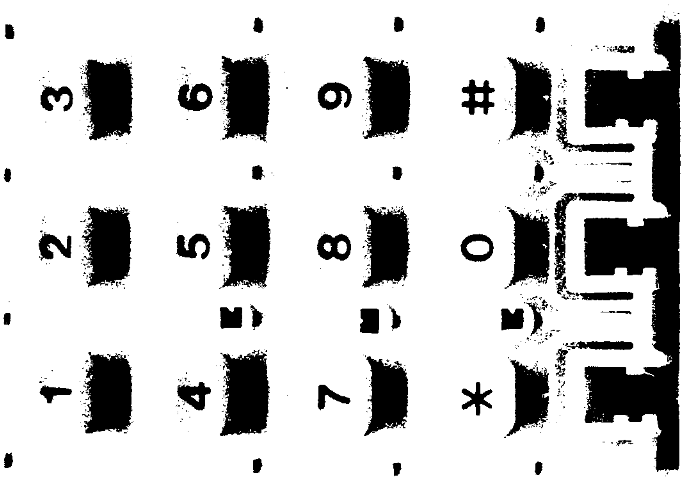


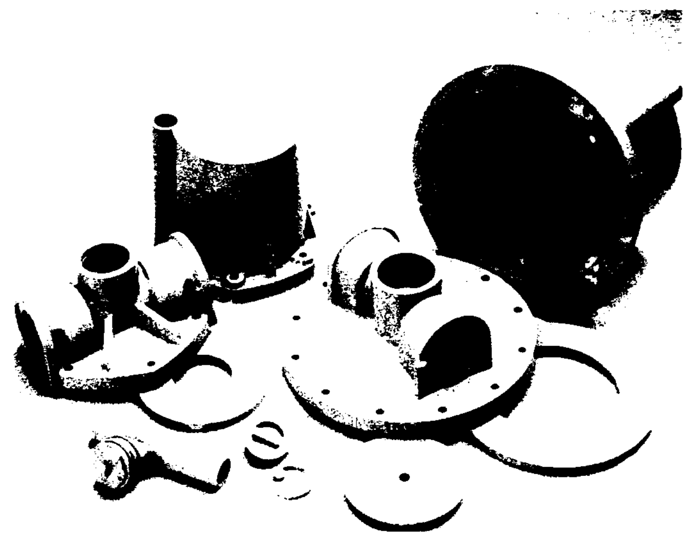
Submersible Pump Components

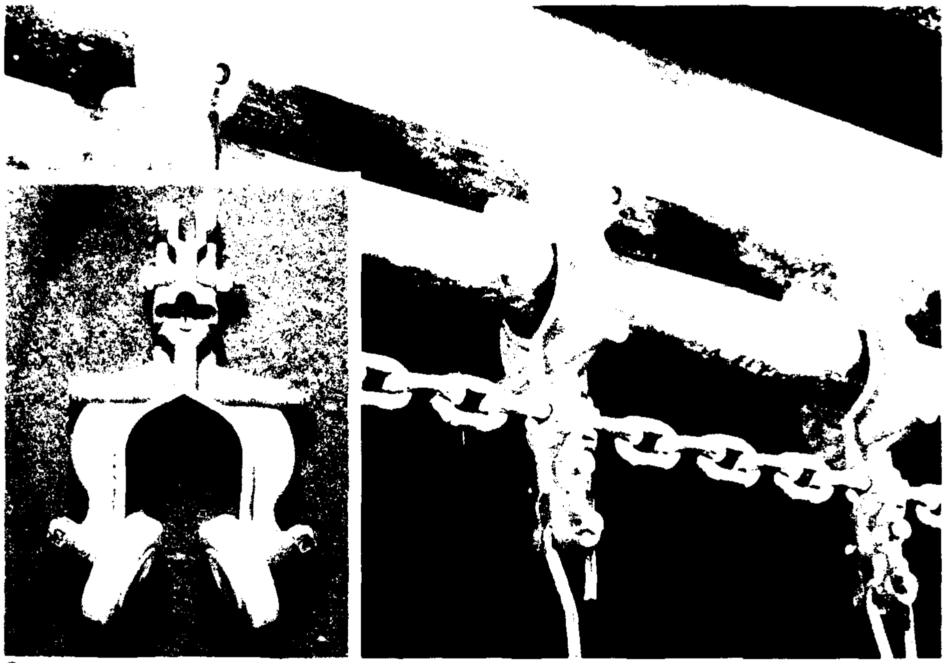




Chemical Spray Nozzles

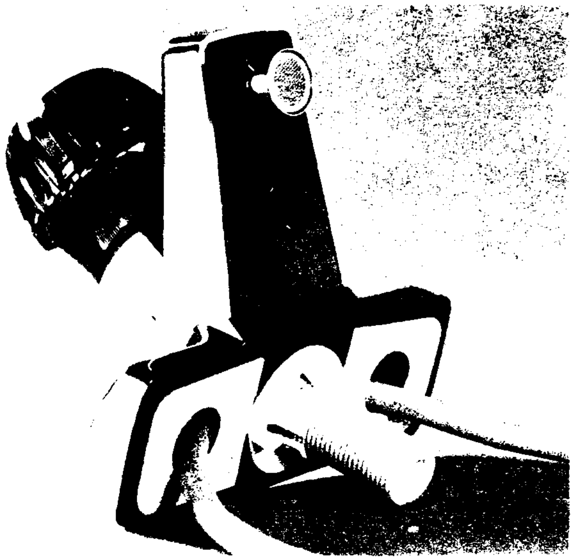




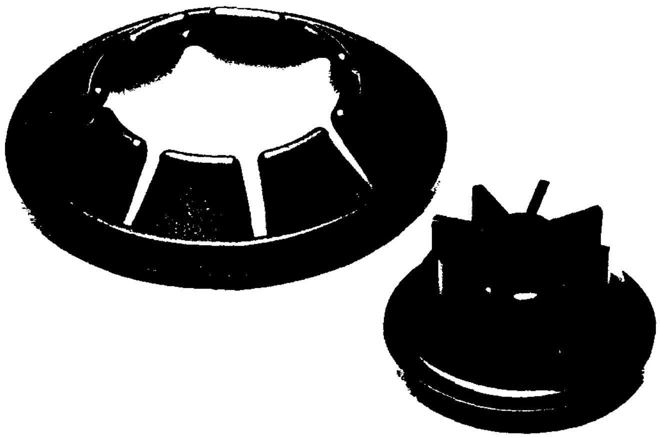


Overhead carriers for poultry processing

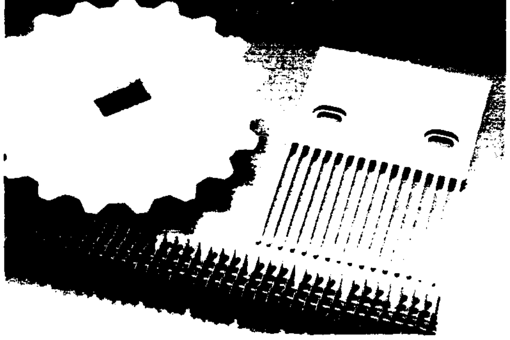
Automotive roll over gas shut off valve



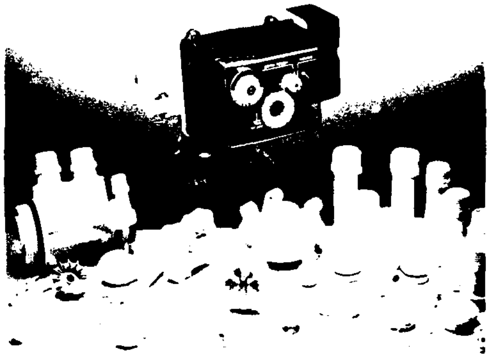
Lavatory handset underbody



Bonding unit for single ply roofing



Conveyor System Components



Water Softner Control Valve

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